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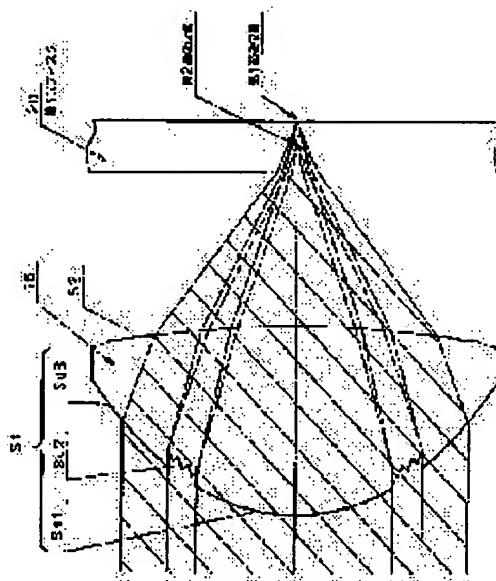
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(54) PICKUP DEVICE FOR RECORDING AND REPRODUCING OF OPTICAL INFORMATION RECORDING MEDIUM, OBJECTIVE LENS, AND DESIGN METHOD FOR OBJECTIVE LENS

(57)Abstract:

PROBLEM TO BE SOLVED: To reproduce plural optical disks with one condensing optical system with a low cost without complication and to cope with even an optical disk of high NA.

SOLUTION: A refracting face S1 on the light source side of an objective lens 16 of an optical pickup device 10 is provided with three split faces Sd1 to Sd3, and the second split face Sd2 is made into a diffracting face. In the case of reproducing of a first optical disk whose transparent substrate has a thickness  $t_1$ , the luminous flux passing first and third split faces Sd2 and Sd3 and 0th-order light through the second split face Sd2 are used; and in the case of reproducing of a second optical disk whose transparent substrate has a thickness  $t_2$  ( $t_2 \neq t_1$ ), the luminous flux passing the first split face Sd1 and first-order light through the second split face are used.



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## CLAIMS

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### [Claim(s)]

[Claim 1] The thickness of the 1st light information record medium of  $t_1$  and a transparence substrate receives [ the thickness of a transparence substrate ] the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). In the optical pickup equipment which an information recording surface is made to condense the flux of light which carried out outgoing radiation from the light source through a transparence substrate by one condensing optical system, records information on an information recording surface, and is reproduced The 1st parting plane near the optical axis located in the center of this optical surface in at least one optical surface which constitutes the above-mentioned condensing optical system, It constitutes from an optical surface divided into the 3rd parting plane located on both sides of the 2nd parting plane between this 1st parting plane. The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above, and the 3rd parting plane when the thickness of a transparence substrate was record playback of the 1st light information record medium of  $t_1$ . The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above when the thickness of a transparence substrate was record playback of the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). Optical pickup equipment characterized by the thing whose numerical aperture by the side of the optical information record medium of the flux of light which passes along the optical-axis side edge of the 2nd parting plane of the above is 0.35 or more, and to do [claim 2] In the design approach of the objective lens of optical pickup equipment of making the flux of light which carried out outgoing radiation to two or more optical information record media with which the thickness of a transparence substrate differs from the light source of wavelength  $\lambda$  condensing In within the limits of the numerical aperture  $NA_1$  by the side of the optical information record medium of the objective lens which needs the thickness of a transparence substrate for record playback of the 1st light information record medium of  $t_1$  While the best wave aberration of the flux of light which made the 1st light information record medium condense through the transparence substrate of thickness  $t_1$  designs the 1st aspheric surface and a common refracting interface so that it may become below  $0.05\lambda$  The yield of the spherical aberration of the flux of light which the thickness of a transparence substrate made the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ) condense by primary light So that it may become less than the yield of the spherical aberration at the time of making the 2nd optical information record medium condense through the 1st aspheric surface The 1st diffraction side over said common refracting interface is designed so that the numerical aperture of the optical-axis side edge may be 0.35 or more. When numerical aperture by the side of the information recording surface of an objective lens required for record playback of the above-mentioned 2nd light information record medium is set to  $NA_2$  (however,  $NA_2 < NA_1$ ) for these 1st aspheric surfaces and the 1st diffraction side, The design approach of the objective lens characterized by designing at least one field of the above-mentioned objective lens by compounding so that the above-mentioned 1st diffraction side may be located in the part which the about two above [ of the 1st aspheric surface of the above /  $NA$  ] flux of light passes [claim 3] The design approach of the objective lens of claim 2 characterized by designing the shaft top radius of curvature of the 1st aspheric surface of the above, and the shaft top radius of curvature of the above-mentioned 1st diffraction side as the same [claim 4] The 1st aspheric surface of the above is the objective lens [claim 5] of claims 2 or 3 characterized by designing that the best wave aberration of the flux of light which passed through the 1st aspheric surface located in an optical-axis side, and the thickness of a transparence substrate made the 2nd light information record medium of  $t_2$  condense rather than the 1st diffraction side to compound is below

0.07 $\lambda$ arms. In the objective lens which makes the flux of light which carried out outgoing radiation to two or more optical information record media with which the thickness of a transparence substrate differs from the light source condense The one refracting interface is set at least within the limits of the numerical aperture NA1 by the side of the optical information record medium of the objective lens which needs the thickness of a transparence substrate for record playback of the 1st light information record medium of t1. The 1st aspheric surface where the best wave aberration of the flux of light which made it condense through the transparence substrate of thickness t1 becomes below 0.05 $\lambda$ arms, The yield of the spherical aberration of the flux of light which the thickness of a transparence substrate made the 2nd light information record medium of t2 (however,  $t_2 \neq t_1$ ) condense the objective lens characterized by constituting from a field compounded so that said 1st diffraction side might be located in the part into which the about two NA [ of the 1st aspheric surface of the above ] flux of light passes through the 1st diffraction side which becomes less than the yield of the spherical aberration at the time of making it condense through the 1st aspheric surface of the above on the 2nd light information record medium -- however NA2 is the numerical aperture by the side of the information recording surface of an objective lens required for record playback of the above-mentioned 2nd light information record medium ( $NA_2 < NA_1$ ).

[Claim 6] The thickness of the 1st light information record medium of t1 and a transparence substrate receives [ the thickness of a transparence substrate ] the 2nd light information record medium of t2 (however,  $t_2 \neq t_1$ ). In the objective lens of the optical pickup equipment which an information recording surface is made to condense the flux of light which carried out outgoing radiation from the light source through a transparence substrate by one condensing optical system, and performs informational record playback the above-mentioned objective lens Oneth of them up to 2ndn+1 (however, n natural number) parting plane sequentially from the 1st parting plane near the optical axis at least division, now the 1st flux of light which gets down and passes the 1st parting plane of the above While using for record playback of the 1st light information record medium, and record playback of the 2nd light information record medium It is the objective lens [claim 7] of the optical pickup equipment characterized by using for record playback of the 1st light information record medium, and record playback of the 2nd light information record medium the flux of light which passes an even number parting plane, and mainly using for record playback of the 1st light information record medium the flux of light which passes the odd number parting plane except the 1st parting plane. In the objective lens of the optical pickup equipment which makes the flux of light from the light source condense as an optical spot through the transparence substrate of an optical information record medium on the information recording surface of an optical information record medium in order to carry out record playback of the information on an optical information record medium While the thickness of a transparence substrate can make it condense using the light source of wavelength  $\lambda_1$  on the information recording surface of the 2nd light information record medium of t2 (however,  $t_2 \neq t_1$ ), the thickness of the 1st light information record medium of t1 and a transparence substrate So that it may be possible to condense on the information recording surface of the 2nd light information record medium even if it is the case where the light source of wavelength  $\lambda_2$  (however,  $\lambda_2 \neq \lambda_1$ ) is used The objective lens of the optical pickup equipment characterized by having constituted the 1st [ at least ] page from two or more parting planes of the above-mentioned objective lens, and having made at least one of the above-mentioned parting planes into the diffraction side, and carrying out as [ be / the numerical aperture of the optical-axis side edge / 0.35 or more ]

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## DETAILED DESCRIPTION

## [Detailed Description of the Invention]

[0001]

[Industrial Application] This invention makes an information recording surface condense the flux of light which carried out outgoing radiation from the light source by condensing optical system, and relates to the design approach of the optical pickup equipment for enforcing the record playback approach of the optical information record medium which carries out record playback of the information on an optical information record medium, and this approach, its objective lens, and this objective lens.

[0002]

[Description of the Prior Art] In recent years, development of DVD which is the optical information record medium of the high density made to large-capacity-ize in magnitude comparable as CD (compact disk) which is the conventional optical information record medium (it is also called an optical disk) was made with utilization of short wavelength red semiconductor laser. In this DVD, numerical aperture NA by the side of the optical disk of the objective lens when using 635nm short wavelength semiconductor laser is set to 0.6. In addition, DVDs are track pitch 0.74micrometer and the 0.4 micrometers of the shortest pit length, and densification is carried out to below one half to track pitch 1.6micrometer of CD, and the 0.83 micrometers of the shortest pit length. Moreover, the optical disk of various specification, for example, CD-R(recordable compact disk) LD(laser disk) MD(mini disc) MO etc., (magneto-optic disk) is commercialized other than CD and DVD which were mentioned above, and it has spread. Need numerical aperture is shown with the thickness of the transparence substrate of various optical disks in Table 1.

[Table 1]

Optical disk Transparence substrate thickness (mm) Need numerical aperture NA (light source wavelength  $\lambda$ nm)

CD, CD-R (playback) 1.20 0.45 ( $\lambda = 780$ )

CD-R (record, playback) 1.20 0.50 ( $\lambda = 780$ )

LD 1.25 0.50 ( $\lambda = 780$ )

MD 1.20 0.45 ( $\lambda = 780$ )

MO (3.5 inches, 230MB) 1.20 0.55 ( $\lambda = 780$ )

MO (3.5 inches, 640MB) 1.20 0.55 ( $\lambda = 680$ )

DVD 0.60 0.60 ( $\lambda = 635$ )

[0003] Among the above-mentioned optical information record medium, about CD-R, although it is necessary to be  $\lambda = 780$ nm in light source wavelength, being able to use the light source of wavelength other than the light source wavelength indicated to Table 1 in other optical disks, and need numerical aperture changing according to the wavelength to be used, for example, approximating by need numerical-aperture  $NA = \lambda$  (micrometer) / 1.06 in the case of need numerical-aperture  $NA = \lambda$  (micrometer) / 1.73, and DVD, when it is CD is known well.

[0004] Thus, since it corresponds to various optical disks with which size, substrate thickness, and recording density differ from operating wavelength etc. variously, the optical pickup equipment which is equipped with the condensing optical system corresponding to each different optical disk, and changes condensing optical system with the optical disk which carries out record playback is proposed. However, with this optical pickup equipment, two or more condensing optical system is needed, the drive for it not only causing cost quantity, but

changing condensing optical system is needed, equipment is complicated, and there is a problem referred to as that that change precision is also required.

[0005] Then, the optical pickup equipment which carries out record playback of two or more optical disks according to one condensing optical system is proposed variously. As one of them, when the refracting interface of an objective lens is divided into ring-like two or more fields and each parting plane carries out image formation of the beam to one of the optical disks with which thickness differs, the optical pickup equipment which carries out record playback is indicated by JP,7-302437,A.

[0006] Moreover, at the time of the 2nd optical disk of the thickness  $t_2$  of a transparence substrate, the optical pickup equipment which forms a condensing spot where a few is defocused is indicated by JP,7-57271,A using the objective lens designed so that the wave aberration which the beam condensed has might become below  $0.07\lambda$  at the time of the 1st optical disk of the thickness  $t_1$  of a transparence substrate.

[0007]

[Problem(s) to be Solved by the Invention] However, in order that the optical pickup equipment of a JP,7-302437,A indication may divide the amount of incident light into two foci with one objective lens, it needs to enlarge a laser output and causes cost quantity. Moreover, at the time of the 2nd optical disk record playback, as for the optical pickup equipment of a JP,7-57271,A indication, the increment in the jitter by the side lobe takes place. With the objective lens by which wave aberration was especially made below  $0.07\lambda$  with the 1st optical disk, since record playback of the 2nd optical disk is carried out forcibly, a limitation is generated in the numerical aperture in which the account rec/play student of the 2nd optical disk is possible.

[0008] The record playback of two or more optical information record media by one condensing optical system can be carried out, it can realize with low cost and a simple configuration, and this invention aims at obtaining the objective lens for the optical pickup equipment for enforcing the record playback approach of the optical information record medium which can be equivalent also to the optical information record medium of further high NA, and this approach, and this pickup.

[0009]

[Means for Solving the Problem] As for the optical pickup equipment of this invention, the thickness of the 1st light information record medium of  $t_1$  and a transparence substrate receives [ the thickness of a transparence substrate ] the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). In the optical pickup equipment which an information recording surface is made to condense the flux of light which carried out outgoing radiation from the light source through a transparence substrate by one condensing optical system, records information on an information recording surface, and is reproduced The 1st parting plane near the optical axis located in the center of this optical surface in at least one optical surface which constitutes the above-mentioned condensing optical system, It constitutes from an optical surface divided into the 3rd parting plane located on both sides of the 2nd parting plane between this 1st parting plane. The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above, and the 3rd parting plane when the thickness of a transparence substrate was record playback of the 1st light information record medium of  $t_1$ . The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above when the thickness of a transparence substrate was record playback of the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). It is characterized by carrying out as [ be / the numerical aperture of the flux of light which passes along the optical-axis side edge / 0.35 or more ].

[0010] In the optical pickup equipment for enforcing the above-mentioned record playback approach the above-mentioned condensing optical system At least one optical surface which constitutes condensing optical system can divide up to  $2n+1$  (however,  $n$  natural number) parting plane sequentially from the 1st parting plane near the optical axis. While using for record playback of the 1st light information record medium, and record playback of the 2nd light information record medium the 1st flux of light which passes the 1st parting plane of the above The flux of light which uses for record playback of the 1st light information record medium and record playback of the 2nd light information record medium the flux of light which passes an even number parting plane, and passes the odd number parting plane except the 1st parting plane is [0011] mainly used for record playback of the 1st light information record medium.

[Embodiment of the Invention] The 1st parting plane near the optical axis which can prepare the above-mentioned parting plane in an objective lens, and is located in the center of an optical surface, It constitutes

from an optical surface divided into the 3rd parting plane located on both sides of the 2nd parting plane between this 1st parting plane. The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above, and the 3rd parting plane when the thickness of a transparence substrate was record playback of the 1st light information record medium of  $t_1$ . In case the thickness of a transparence substrate is record playback of the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ), the beam spot can be formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above.

[0012] At this time, an objective lens is set within the limits of the numerical aperture  $NA_1$  by the side of the optical information record medium which needs the thickness of a transparence substrate for record playback of the 1st light information record medium of  $t_1$ . While the best wave aberration of the flux of light which made the 1st light information record medium condense through the transparence substrate of thickness  $t_1$  designs the 1st aspheric surface and a common refracting interface so that it may become below  $0.05\lambda$  rms. The yield of the spherical aberration of the flux of light which the thickness of a transparence substrate made the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ) condense by primary light. The 1st diffraction side over said common refracting interface is designed so that the numerical aperture of the optical-axis side edge may be 0.35 or more, so that it may become less than the yield of the spherical aberration at the time of making the 2nd optical information record medium condense through the 1st aspheric surface. When performing record playback of the 1st light information record medium, it cannot avoid that the flux of light for the 2nd light information record media diffracted by the diffraction side serves as the flare. If the incoming beams to an objective lens are Gaussian distribution, since the optical reinforcement near an optical axis is large, if numerical aperture is made small, a part with this large reinforcement will be diffracted, the spot quantity of light runs short, and, on the other hand, a bottom jitter gets worse. Therefore, as for the numerical aperture of the optical-axis side edge of the diffraction side which is the 2nd parting plane, it is desirable that it is 0.35 or more. It compounds so that the above-mentioned 1st diffraction side may be located in the part into which the about two above [ of the 1st aspheric surface of the above /  $NA$  ] flux of light passes through these 1st aspheric surfaces and the 1st diffraction side when numerical aperture by the side of the information recording surface of an objective lens required for record playback of the above-mentioned 2nd light information record medium is set to  $NA_2$  (however,  $NA_2 < NA_1$ ). It is desirable to design the shaft top radius of curvature of the 1st aspheric surface of the above and the shaft top radius of curvature of the above-mentioned 1st diffraction side as the same at this time, and, as for the 1st aspheric surface of the above, it is more desirable than the 1st diffraction side to compound for the best wave aberration of the flux of light which passed through the 1st aspheric surface located in an optical-axis side, and the thickness of a transparence substrate made the 2nd light information record medium of  $t_2$  condense to be below  $0.07\lambda$  rms. An example explains the configuration of an objective lens and it is more concretely carried out to a publication.

[0013]

[Example] With reference to a drawing, an example explains this invention to a detail further below. In advance of an example, the optical pickup equipment which carries out this invention is explained. Drawing 5 is the conceptual diagram showing the configuration of the optical pickup equipment which carries out this invention, and optical pickup equipment 10 consists of a two-dimensional actuator 15 for the semiconductor laser 11 which is the light source, a polarization beam splitter 12, a collimator lens 13, the  $1/4\lambda$  plate 14, diaphragm 17, an objective lens 16, the cylindrical lens 18 that is an astigmatism component, a photodetector 30, focal control, and tracking control etc.

[0014] The flux of light from the semiconductor laser 11 which is the light source penetrates a polarization beam splitter 12, a collimator lens 13, and the  $1/4\lambda$  plate 14, turns into the parallel flux of light of the circular polarization of light, a rat tail is minded according to diaphragm 17, and it minds the transparence substrate 21 of an optical disk 20 with an objective lens 16, and is condensed on the information recording surface 22. It becomes convergence light again by the objective lens 16, the  $1/4\lambda$  plate 14, and the collimator lens 13, and reflects by the polarization beam splitter 12, and incidence of the reflected light bundle modulated by the information pit by the information recording surface 22 is carried out to a photodetector 30 through a cylindrical lens 18. The reading signal of the information by which information record was carried out is acquired by the optical disk 20 using the output signal. On the other hand, the quantity of light distribution change by the formation of a form status change of the spot on a photodetector 30 is detected, and focus



detection and truck detection are performed. An objective lens 16 is moved in the direction perpendicular to an optical axis so that an objective lens 16 may be moved in the direction of an optical axis so that a focal error signal and tracking error signal may be generated by the arithmetic circuit which is not illustrated as everyone knows using the output from a photodetector 30 and the two-dimensional actuator 15 may carry out image formation of the flux of light on the information recording surface 22 based on this focus error signal, and image formation of the flux of light may be carried out to coincidence on a predetermined truck based on a tracking error signal.

[0015] in such optical pickup equipment 10, in case the thickness of a transparence substrate carries out record playback of the 1st optical disk of  $t_1$ , for example, the DVD, ( $t_1=0.6\text{mm}$ ), the beam spot forms circle of least confusion -- as (best focus) -- an objective lens 16 is driven with the two-dimensional actuator 15. Using this objective lens 16, by  $t_2$  (preferably  $t_2 > t_1$ ) in which the thickness of a transparence substrate differs from  $t_1$  The 2nd optical disk with information recording density lower than the 1st optical disk, for example, in case record playback of the CD ( $t_2=1.2\text{mm}$ ) is carried out Spherical aberration occurs in what the thickness of a transparence substrate differs (it becomes it is desirable and large), and spot size cannot read the pit (information) of the 2nd optical disk greatly in the location (it is a back location from a paraxial-focus location) where the beam spot serves as circle of least confusion. However, in the before side location (front focus) near [ location / used as this circle of least confusion ] an objective lens 16, although the magnitude of the whole spot is larger than circle of least confusion, the flare which is unnecessary light is formed in the perimeter of the nucleus which the quantity of light concentrated on the center section, and a nucleus. This nucleus is used in order to read the pit (information) of the 2nd optical disk, and at the time of the 2nd optical disk record playback, the two-dimensional actuator 15 is driven so that it may be in a defocusing (front focus) condition about an objective lens 16.

[0016] Next, in order to play the 1st optical disk and the 2nd optical disk with which the thickness of the above transparence substrates differs with one optical pickup equipment 10, the example which carried out this invention to the objective lens 16 is explained. Drawing 1 is the sectional view having shown the objective lens 16 typically. In addition, the alternate long and short dash line shows the optical axis. The 1st optical disk 20 of illustration of the thickness  $t_1$  of the transparence substrate is thinner than the thickness  $t_2$  of the transparence substrate of the 2nd optical disk, and its information recording density is larger than the 2nd optical disk.

[0017] In this example, an objective lens 16 is a convex lens with the forward refractive power which both the field S1 by the side of the light source and the refracting interface S2 by the side of an optical disk 20 presented the aspheric surface configuration. Moreover, the field S1 by the side of the light source of an objective lens 16 consists of the 1st parting plane Sd1 of plurality (this example three) - the 3rd parting plane Sd3 an optical axis and in the shape of a said alignment. The boundary of parting planes Sd1-Sd3 prepares a level difference, and the hologram is formed in the 2nd parting plane Sd2. The flux of light (the 1st flux of light) which passes the 1st parting plane Sd1 including an optical axis in this objective lens 16 is used for playback of the information recorded on the informational playback and the 2nd informational optical disk which were recorded on the 1st optical disk. Zero-order light mainly uses the flux of light (the 2nd flux of light) diffracted by the 2nd parting plane Sd2 outside the 1st parting plane Sd1 for playback of the information by which the 1st optical disk and the primary diffracted light were recorded on the 2nd disk. The flux of light (the 3rd flux of light) which passes the 3rd parting plane Sd3 outside the 2nd parting plane Sd2 serves as a configuration which is used for playback of the information mainly recorded on the 1st optical disk.

[0018] Thus, the 1st flux of light near the optical axis is used for playback of the 1st optical disk, and playback of the 2nd optical disk for the flux of light by which outgoing radiation is carried out from the light source. By using the 2nd flux of light outside the 1st flux of light for playback of the 1st optical disk and the 2nd optical disk, and mainly using the 3rd flux of light outside the 2nd flux of light for playback of the 1st optical disk It becomes reproducible [ the optical disk of plurality (this example two) ] by one condensing optical system about the light from the light source, suppressing quantity of light loss. And although the great portion of 3rd flux of light is unnecessary light at the time of playback of the 2nd optical disk, since this unnecessary light is not used for playback of the 2nd optical disk in this case, the diaphragm 17 is only made into numerical aperture required for playback of the 1st optical disk, and it can reproduce, without needing at all a means to change the numerical aperture of diaphragm 17.

[0019] When it furthermore explains in full detail, the objective lens 16 of this example The 1st flux of light



which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 in case the 1st optical disk is played (refer to drawing 2 ), the 3rd flux of light (flux of light shown with a slash), and the zero-order diffracted light of the 2nd parting plane Sd2 Carrying out image formation to the almost same 1st image formation location, the wave aberration (wave aberration except the 2nd flux of light which passes the 2nd parting plane Sd2) has become below  $0.05\lambda$  (lambda is the wavelength of the light source here). Thereby, playback of the 1st optical disk is performed by the 1st flux of light, the 2nd flux of light, and the 3rd flux of light.

[0020] At this time, image formation of the primary diffracted light (flux of light shown with a broken line) of the 2nd flux of light which passes the 2nd parting plane Sd2 is carried out to the different 2nd image formation location from the 1st image formation location. This 2nd image formation location will be made into -27-micrometer or more distance of -4 micrometers or less from the 1st image formation location, if the 1st image formation location is set to 0 (zero), an objective lens 16 side is made negative and it makes that opposite side more nearly forward than it (the 2nd image formation location is brought close to an objective lens from the 1st image formation location.). If spherical aberration will amend too much, a next door and the spot situation at the time of playback of the 1st optical disk will worsen, if -27 micrometers of this minimum are exceeded, and -4 micrometers of upper limits are exceeded, the diameter of a spot at the time of playback of the 2nd optical disk and a side lobe will become large. In addition, although the 2nd image formation location was set to -27 micrometers - 4 micrometers from the 1st image formation location in this example since it was  $t_2$  and  $t_1 < NA_1 > NA_2$ , in  $t_1 > t_2$  and  $NA_1 < NA_2$ , the 2nd image formation location is set to 4 micrometers - 27 micrometers from the 1st image formation location.

[0021] moreover, in case the above-mentioned objective lens 16 is used for playback of the 2nd optical disk which has the transparence substrate of predetermined thickness ( $t_2=1.2\text{mm}$ ) The location at which the beam of light which passes near the optical axis among the 1st flux of light (an upward slash shows) crosses an optical axis in the case of the predetermined flux of light (parallel flux of light) which carries out incidence to an objective lens 166 as shown in drawing 2 , between the locations at which the beam of light which passes through the edge (the 2nd parting plane Sd2 side) of the 1st parting plane Sd1 towards intersecting perpendicularly with an optical axis crosses an optical axis, the primary diffracted light of the 2nd flux of light (the bottom of a right shoulder shows with the slash of \*\*) crosses an optical axis (image formation is carried out) -- it becomes like. Therefore, the 1st flux of light and the 2nd flux of light are condensed near the information recording surface of the 2nd optical disk, and playback of the 2nd optical disk is performed. Although the 3rd flux of light (shown by the broken line to the middle) serves as the flare at this time, it becomes reproducible [ the 2nd optical disk ] by the nucleus formed by the 1st flux of light and the 2nd flux of light.

[0022] Each flux of light which divided this invention so that it might correspond to each optical disk which reproduces the 2nd flux of light which uses for playback of all reproducible optical disks the 1st flux of light which passes near [ where a numerical aperture is small ] the optical axis, and passes outside the 1st parting plane when put in another way, and was divided is used for playback of each optical disk (this example the 1st and 2nd optical disk). Furthermore, the flux of light (this example the 3rd flux of light) which is separated from the 1st flux of light among the divided flux of lights is used for playback of an optical disk with a larger numerical aperture required in order to reproduce the information on an optical disk (this example the 1st optical disk).

[0023] If such optical system (this example objective lens 16) is used, numerical aperture NA2 required for playback of the 2nd optical disk can be enlarged by becoming possible to play two or more disks with which the thickness of a transparence substrate differs by one optical system, and being able to set the diameter of a parting plane as arbitration. Moreover, quantity of light loss of the flux of light from the light source decreases by using the flux of light near the optical axis for playback of two or more optical disks. And at the time of the 2nd optical disk playback, the side lobe of the beam spot is decreased, a nucleus with strong beam reinforcement is formed, and exact information is acquired. Furthermore, two or more disks can be played by one condensing optical system, without needing a special means to change the numerical aperture of diaphragm 17.

[0024] In addition, in this example, although parting planes Sd1-Sd3 and a diffraction side were established in the field S1 by the side of the light source of an objective lens 16, you may prepare in the refracting interface by the side of a disk 20; and such [ one ] a function of the optical elements (for example, collimator lens 13 etc.) of

other condensing optical system may be given, and the optical element which still more newly has such a function may be prepared on an optical path. Moreover, it may decompose into a different optical element and the function of each parting planes Sd1-Sd3 may be prepared.

[0025] Moreover, although the so-called objective lens 16 of the infinity system which used the collimator lens 13 was used in this example, there is no collimator lens 13 and you may apply to an objective lens in which the emission light through the lens from which the emission light from the light source subtracts the emission degree of direct or emission light carries out incidence, and an objective lens with which the convergence light carries out incidence of the flux of light from the light source using the coupling lens changed into convergence light.

[0026] Moreover, what is necessary is just to constitute not only from this but from at least three parting planes or more at this example, although the field S1 was constituted from three parting planes Sd1-Sd3. For example, when [ this ] a field S1 is constituted from five parting planes Sd1-Sd5, When the 2nd and 4th parting planes are made into a hologram and numerical aperture of the boundary of NA3, the 4th parting plane, and the 5th parting plane is set to NA4 for the numerical aperture of the boundary of the 3rd parting plane and the 4th parting plane, It is desirable to satisfy the conditions of  $0.60(NA2) < NA3 < 1.3 (NA2)$  and  $0.01 < NA4 - NA3 < 0.12$ . The disk of the big need numerical aperture as the 2nd optical disk can be played without this dropping the reinforcement of the optical spot which the 1st disk is made to condense. Furthermore, as for the upper limit of NA3, it is desirable practically that it is  $NA3 < 1.1 (NA2)$ , and the minimum of NA3 has desirable  $0.80(NA2) < NA3$ , and it is desirable practically to a pan that it is  $0.85(NA2) < NA3$ . Moreover, as for the upper limit of NA4-NA3, it is desirable that it is  $NA4 - NA3 < 0.1$ .

[0027] Moreover, when an objective lens 16 is seen from the light source, although the hologram of the shape of an annulus of the shape of an optical axis and a concentric circle was prepared, it is not restricted to this but Fresnel may constitute the 2nd parting plane Sd2 from this example. In addition, one side of the flux of light divided into zero-order light and primary light is used for playback of the 1st optical disk, and another side is used for playback of the 2nd optical disk. At this time, the quantity of light of the flux of light used for playback of the 2nd optical disk may be enlarged. Furthermore, although the diffraction side which mainly uses zero-order light and primary light was established, it is good also as a diffraction side which considers as the diffraction side using primary light and secondary light, or uses high order light.

[0028] The best wave aberration by the flux of light which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 in this example in case the 1st disk is played (namely, when the transparence substrate of thickness t1 is minded) Moreover,  $0.05\lambda$  arms It not only fills (however, the wavelength of the light source used in case  $\lambda(nm)$  plays the 1st disk), but Furthermore,  $0.07\lambda$  arms whose best wave aberration by the flux of light which passes the 1st parting plane Sd1 in case the 2nd optical disk is played (namely, when the transparence substrate of thickness t2 is minded) is a diffraction limitation The regenerative signal of the 2nd optical disk can be made good by filling (however, the wavelength of the light source used in case  $\lambda(nm)$  plays the 2nd disk).

[0029] Next, the spherical-aberration Fig. of an objective lens 16 is explained about the 2nd example with reference to drawing 3 which is drawing shown typically. In drawing 3, (a) is the spherical aberration when minding playback, i.e., the transparence substrate of thickness t1, for the 1st disk, and (b) is the spherical aberration when minding playback, i.e., the transparence substrate of thickness t2 (this example  $t2 > t1$ ), for the 2nd disk. The need numerical aperture by the side of the optical disk of condensing optical system required in order to reproduce the information on NA1 and the 2nd optical disk for the need numerical aperture by the side of the optical disk of condensing optical system required here in order to reproduce the information on the 1st optical disk NA2 The numerical aperture by the side of the optical disk of the flux of light which passes through a boundary with the parting planes Sd2 and Sd3 of neuroleptanalgesia and an objective lens 16 the numerical aperture by the side of (however,  $NA2 < NA1$ ) and the optical disk of the flux of light which passes through a boundary with the parting planes Sd1 and Sd2 of an objective lens 16 is set to NAH.

[0030] In addition, the part which, as for the 2nd example, the objective lens 16 indicated as the 1st above-mentioned example is looked at from another viewpoint (spherical aberration, a configuration, wave aberration, etc.), and is not indicated below is the same as that of the above-mentioned example.

[0031] An objective lens 16 like the 1st example of the above designs the 1st aspheric surface (zona-orbicularis-like parting plane) of the 1st refracting interface S1, and the 2nd refracting interface S2 (common refracting

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention makes an information recording surface condense the flux of light which carried out outgoing radiation from the light source by condensing optical system, and relates to the design approach of the optical pickup equipment for enforcing the record playback approach of the optical information record medium which carries out record playback of the information on an optical information record medium, and this approach, its objective lens, and this objective lens.

[0002]

[Description of the Prior Art] In recent years, development of DVD which is the optical information record medium of the high density made to large-capacity-size in magnitude comparable as CD (compact disk) which is the conventional optical information record medium (it is also called an optical disk) was made with utilization of short wavelength red semiconductor laser. In this DVD, numerical aperture NA by the side of the optical disk of the objective lens when using 635nm short wavelength semiconductor laser is set to 0.6. In addition, DVDs are track pitch 0.74micrometer and the 0.4 micrometers of the shortest pit length, and densification is carried out to below one half to track pitch 1.6micrometer of CD, and the 0.83 micrometers of the shortest pit length. Moreover, the optical disk of various specification, for example, CD-R(recordable compact disk) LD(laser disk) MD(mini disc) MO etc., (magneto-optic disk) is commercialized other than CD and DVD which were mentioned above, and it has spread. Need numerical aperture is shown with the thickness of the transparence substrate of various optical disks in Table 1.

[Table 1]

Optical disk	Transparence substrate thickness (mm)	Need numerical aperture NA (light source wavelength lambda nm)
CD, CD-R (playback)	1.20 0.45	(lambda= 780)
CD-R (record, playback)	1.20 0.50	(lambda= 780)
LD	1.25 0.50	(lambda= 780)
MD	1.20 0.45	(lambda= 780)
MO (3.5 inches, 230MB)	1.20 0.55	(lambda= 780)
MO (3.5 inches, 640MB)	1.20 0.55	(lambda= 680)
DVD	0.60 0.60	(lambda= 635)

[0003] Among the above-mentioned optical information record medium, about CD-R, although it is necessary to be lambda= 780nm in light source wavelength, being able to use the light source of wavelength other than the light source wavelength indicated to Table 1 in other optical disks, and need numerical aperture changing according to the wavelength to be used, for example, approximating by need numerical-aperture  $NA = \lambda (\text{micrometer}) / 1.06$  in the case of need numerical-aperture  $NA = \lambda (\text{micrometer}) / 1.73$ , and DVD, when it is CD is known well.

[0004] Thus, since it corresponds to various optical disks with which size, substrate thickness, and recording density differ from operating wavelength etc. variously, the optical pickup equipment which is equipped with the condensing optical system corresponding to each different optical disk, and changes condensing optical system with the optical disk which carries out record playback is proposed. However, with this optical pickup equipment, two or more condensing optical system is needed, the drive for it not only causing cost quantity, but changing condensing optical system is needed, equipment is complicated, and there is a problem referred to as that that change precision is also required.

[0005] Then, the optical pickup equipment which carries out record playback of two or more optical disks according to one condensing optical system is proposed variously. As one of them, when the refracting interface of an objective lens is divided into ring-like two or more fields and each parting plane carries out image formation of the beam to one of the optical disks with which thickness differs, the optical pickup equipment which carries out record playback is indicated by JP,7-302437,A.

[0006] Moreover, at the time of the 2nd optical disk of the thickness  $t_2$  of a transparence substrate, the optical pickup

equipment which forms a condensing spot where a few is defocused is indicated by JP,7-57271,A using the objective lens designed so that the wave aberration which the beam condensed has might become below  $0.07\lambda$  at the time of the 1st optical disk of the thickness  $t_1$  of a transparence substrate.

[0007]

[Problem(s) to be Solved by the Invention] However, in order that the optical pickup equipment of a JP,7-302437,A indication may divide the amount of incident light into two foci with one objective lens, it needs to enlarge a laser output and causes cost quantity. Moreover, at the time of the 2nd optical disk record playback, as for the optical pickup equipment of a JP,7-57271,A indication, the increment in the jitter by the side lobe takes place. With the objective lens by which wave aberration was especially made below  $0.07\lambda$  with the 1st optical disk, since record playback of the 2nd optical disk is carried out forcibly, a limitation is generated in the numerical aperture in which the account rec/play student of the 2nd optical disk is possible.

[0008] The record playback of two or more optical information record media by one condensing optical system can be carried out, it can realize with low cost and a simple configuration, and this invention aims at obtaining the objective lens for the optical pickup equipment for enforcing the record playback approach of the optical information record medium which can be equivalent also to the optical information record medium of further high NA, and this approach, and this pickup.

[0009]

[Means for Solving the Problem] As for the optical pickup equipment of this invention, the thickness of the 1st light information record medium of  $t_1$  and a transparence substrate receives [ the thickness of a transparence substrate ] the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). In the optical pickup equipment which an information recording surface is made to condense the flux of light which carried out outgoing radiation from the light source through a transparence substrate by one condensing optical system, records information on an information recording surface, and is reproduced The 1st parting plane near the optical axis located in the center of this optical surface in at least one optical surface which constitutes the above-mentioned condensing optical system, It constitutes from an optical surface divided into the 3rd parting plane located on both sides of the 2nd parting plane between this 1st parting plane. The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above, and the 3rd parting plane when the thickness of a transparence substrate was record playback of the 1st light information record medium of  $t_1$ . The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above when the thickness of a transparence substrate was record playback of the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ). It is characterized by carrying out as [ be / the numerical aperture of the flux of light which passes along the optical-axis side edge / 0.35 or more ].

[0010] In the optical pickup equipment for enforcing the above-mentioned record playback approach the above-mentioned condensing optical system At least one optical surface which constitutes condensing optical system can divide up to  $2n+1$  (however,  $n$  natural number) parting plane sequentially from the 1st parting plane near the optical axis. While using for record playback of the 1st light information record medium, and record playback of the 2nd light information record medium the 1st flux of light which passes the 1st parting plane of the above The flux of light which uses for record playback of the 1st light information record medium and record playback of the 2nd light information record medium the flux of light which passes an even number parting plane, and passes the odd number parting plane except the 1st parting plane is [0011] mainly used for record playback of the 1st light information record medium.

[Embodiment of the Invention] The 1st parting plane near the optical axis which can prepare the above-mentioned parting plane in an objective lens, and is located in the center of an optical surface, It constitutes from an optical surface divided into the 3rd parting plane located on both sides of the 2nd parting plane between this 1st parting plane. The beam spot is formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above, and the 3rd parting plane when the thickness of a transparence substrate was record playback of the 1st light information record medium of  $t_1$ . In case the thickness of a transparence substrate is record playback of the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ), the beam spot can be formed according to the flux of light diffracted by the flux of light and the 2nd parting plane which passed the 1st parting plane of the above.

[0012] At this time, an objective lens is set within the limits of the numerical aperture NA1 by the side of the optical information record medium which needs the thickness of a transparence substrate for record playback of the 1st light information record medium of  $t_1$ . While the best wave aberration of the flux of light which made the 1st light information record medium condense through the transparence substrate of thickness  $t_1$  designs the 1st aspheric surface and a common refracting interface so that it may become below  $0.05\lambda$  The yield of the spherical aberration of the flux of light which the thickness of a transparence substrate made the 2nd light information record medium of  $t_2$  (however,  $t_2 \neq t_1$ ) condense by primary light The 1st diffraction side over said common refracting interface is designed

so that the numerical aperture of the optical-axis side edge may be 0.35 or more, so that it may become less than the yield of the spherical aberration at the time of making the 2nd optical information record medium condense through the 1st aspheric surface. When performing record playback of the 1st light information record medium, it cannot avoid that the flux of light for the 2nd light information record media diffracted by the diffraction side serves as the flare. If the incoming beams to an objective lens are Gaussian distribution, since the optical reinforcement near an optical axis is large, if numerical aperture is made small, a part with this large reinforcement will be diffracted, the spot quantity of light runs short, and, on the other hand, a bottom jitter gets worse. Therefore, as for the numerical aperture of the optical-axis side edge of the diffraction side which is the 2nd parting plane, it is desirable that it is 0.35 or more. It compounds so that the above mentioned 1st diffraction side may be located in the part into which the about two above [ of the 1st aspheric surface of the above / NA ] flux of light passes through these 1st aspheric surfaces and the 1st diffraction side when numerical aperture by the side of the information recording surface of an objective lens required for record playback of the above-mentioned 2nd light information record medium is set to NA2 (however,  $NA2 < NA1$ ). It is desirable to design the shaft top radius of curvature of the 1st aspheric surface of the above and the shaft top radius of curvature of the above-mentioned 1st diffraction side as the same at this time, and, as for the 1st aspheric surface of the above, it is more desirable than the 1st diffraction side to compound for the best wave aberration of the flux of light which passed through the 1st aspheric surface located in an optical-axis side, and the thickness of a transparence substrate made the 2nd light information record medium of t2 condense to be below  $0.07\lambda$  arms. An example explains the configuration of an objective lens and it is more concretely carried out to a publication.

[0013]

[Example] With reference to a drawing, an example explains this invention to a detail further below. In advance of an example, the optical pickup equipment which carries out this invention is explained. Drawing 5 is the conceptual diagram showing the configuration of the optical pickup equipment which carries out this invention, and optical pickup equipment 10 consists of a two-dimensional actuator 15 for the semiconductor laser 11 which is the light source, a polarization beam splitter 12, a collimator lens 13, the  $1/4\lambda$  plate 14, diaphragm 17, an objective lens 16, the cylindrical lens 18 that is an astigmatism component, a photodetector 30, focal control, and tracking control etc.

[0014] The flux of light from the semiconductor laser 11 which is the light source penetrates a polarization beam splitter 12, a collimator lens 13, and the  $1/4\lambda$  plate 14, turns into the parallel flux of light of the circular polarization of light, a rat tail is minded according to diaphragm 17, and it minds the transparence substrate 21 of an optical disk 20 with an objective lens 16, and is condensed on the information recording surface 22. It becomes convergence light again by the objective lens 16, the  $1/4\lambda$  plate 14, and the collimator lens 13, and reflects by the polarization beam splitter 12, and incidence of the reflected light bundle modulated by the information pit by the information recording surface 22 is carried out to a photodetector 30 through a cylindrical lens 18. The reading signal of the information by which information record was carried out is acquired by the optical disk 20 using the output signal. On the other hand, the quantity of light distribution change by the formation of a form status change of the spot on a photodetector 30 is detected, and focus detection and truck detection are performed. An objective lens 16 is moved in the direction perpendicular to an optical axis so that an objective lens 16 may be moved in the direction of an optical axis so that a focal error signal and tracking error signal may be generated by the arithmetic circuit which is not illustrated as everyone knows using the output from a photodetector 30 and the two-dimensional actuator 15 may carry out image formation of the flux of light on the information recording surface 22 based on this focus error signal, and image formation of the flux of light may be carried out to coincidence on a predetermined truck based on a tracking error signal.

[0015] in such optical pickup equipment 10, in case the thickness of a transparence substrate carries out record playback of the 1st optical disk of t1, for example, the DVD, ( $t1=0.6\text{mm}$ ), the beam spot forms circle of least confusion -- as (best focus) -- an objective lens 16 is driven with the two-dimensional actuator 15. Using this objective lens 16, by t2 (preferably  $t2 > t1$ ) in which the thickness of a transparence substrate differs from t1 The 2nd optical disk with information recording density lower than the 1st optical disk, for example, in case record playback of the CD ( $t2=1.2\text{mm}$ ) is carried out Spherical aberration occurs in what the thickness of a transparence substrate differs (it becomes it is desirable and large), and spot size cannot read the pit (information) of the 2nd optical disk greatly in the location (it is a back location from a paraxial-focus location) where the beam spot serves as circle of least confusion. However, in the before side location (front focus) near [ location / used as this circle of least confusion ] an objective lens 16, although the magnitude of the whole spot is larger than circle of least confusion, the flare which is unnecessary light is formed in the perimeter of the nucleus which the quantity of light concentrated on the center section, and a nucleus. This nucleus is used in order to read the pit (information) of the 2nd optical disk, and at the time of the 2nd optical disk record playback, the two-dimensional actuator 15 is driven so that it may be in a defocusing (front focus) condition about an objective lens 16.

[0016] Next, in order to play the 1st optical disk and the 2nd optical disk with which the thickness of the above



transparence substrates differs with one optical pickup equipment 10, the example which carried out this invention to the objective lens 16 is explained. Drawing 1 is the sectional view having shown the objective lens 16 typically. In addition, the alternate long and short dash line shows the optical axis. The 1st optical disk 20 of illustration of the thickness  $t_1$  of the transparence substrate is thinner than the thickness  $t_2$  of the transparence substrate of the 2nd optical disk, and its information recording density is larger than the 2nd optical disk.

[0017] In this example, an objective lens 16 is a convex lens with the forward refractive power which both the field S1 by the side of the light source and the refracting interface S2 by the side of an optical disk 20 presented the aspheric surface configuration. Moreover, the field S1 by the side of the light source of an objective lens 16 consists of the 1st parting plane Sd1 of plurality (this example three), the 2nd parting plane Sd2, and the 3rd parting plane Sd3 an optical axis and in the shape of a said alignment. The boundary of parting planes Sd1-Sd3 prepares a level difference, and the hologram is formed in the 2nd parting plane Sd2. The flux of light (the 1st flux of light) which passes the 1st parting plane Sd1 including an optical axis in this objective lens 16 is used for playback of the information recorded on the informational playback and the 2nd informational optical disk which were recorded on the 1st optical disk. Zero-order light mainly uses the flux of light (the 2nd flux of light) diffracted by the 2nd parting plane Sd2 outside the 1st parting plane Sd1 for playback of the information by which the 1st optical disk and the primary diffracted light were recorded on the 2nd disk. The flux of light (the 3rd flux of light) which passes the 3rd parting plane Sd3 outside the 2nd parting plane Sd2 serves as a configuration which is used for playback of the information mainly recorded on the 1st optical disk.

[0018] Thus, the 1st flux of light near the optical axis is used for playback of the 1st optical disk, and playback of the 2nd optical disk for the flux of light by which originating radiation is carried out from the light source. By using the 2nd flux of light outside the 1st flux of light for playback of the 1st optical disk and the 2nd optical disk, and mainly using the 3rd flux of light outside the 2nd flux of light for playback of the 1st optical disk It becomes reproducible [ the optical disk of plurality (this example two) ] by one condensing optical system about the light from the light source, suppressing quantity of light loss. And although the great portion of 3rd flux of light is unnecessary light at the time of playback of the 2nd optical disk, since this unnecessary light is not used for playback of the 2nd optical disk in this case, the diaphragm 17 is only made into numerical aperture required for playback of the 1st optical disk, and it can reproduce, without needing at all a means to change the numerical aperture of diaphragm 17.

[0019] When it furthermore explains in full detail, the objective lens 16 of this example The 1st flux of light which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 in case the 1st optical disk is played (refer to drawing 2 ), the 3rd flux of light (flux of light shown with a slash), and the zero-order diffracted light of the 2nd parting plane Sd2 Carrying out image formation to the almost same 1st image formation location, the wave aberration (wave aberration except the 2nd flux of light which passes the 2nd parting plane Sd2) has become below  $0.05\lambda$  (lambda is the wavelength of the light source here). Thereby, playback of the 1st optical disk is performed by the 1st flux of light, the 2nd flux of light, and the 3rd flux of light.

[0020] At this time, image formation of the primary diffracted light (flux of light shown with a broken line) of the 2nd flux of light which passes the 2nd parting plane Sd2 is carried out to the different 2nd image formation location from the 1st image formation location. This 2nd image formation location will be made into -27-micrometer or more distance of -4 micrometers or less from the 1st image formation location, if the 1st image formation location is set to 0 (zero), an objective lens 16 side is made negative and it makes that opposite side more nearly forward than it (the 2nd image formation location is brought close to an objective lens from the 1st image formation location.). If spherical aberration will amend too much, a next door and the spot situation at the time of playback of the 1st optical disk will worsen, if -27 micrometers of this minimum are exceeded, and -4 micrometers of upper limits are exceeded, the diameter of a spot at the time of playback of the 2nd optical disk and a side lobe will become large. In addition, although the 2nd image formation location was set to -27 micrometers - -4 micrometers from the 1st image formation location in this example since it was  $t_2$  and  $t_1 < NA_1 > NA_2$ , in  $t_1 > t_2$  and  $NA_1 < NA_2$ , the 2nd image formation location is set to 4 micrometers - 27 micrometers from the 1st image formation location.

[0021] moreover, in case the above-mentioned objective lens 16 is used for playback of the 2nd optical disk which has the transparence substrate of predetermined thickness ( $t_2=1.2\text{mm}$ ) The location at which the beam of light which passes near the optical axis among the 1st flux of light (an upward slash shows) crosses an optical axis in the case of the predetermined flux of light (parallel flux of light) which carries out incidence to an objective lens 166 as shown in drawing 2 , between the locations at which the beam of light which passes through the edge (the 2nd parting plane Sd2 side) of the 1st parting plane Sd1 towards intersecting perpendicularly with an optical axis crosses an optical axis, the primary diffracted light of the 2nd flux of light (the bottom of a right shoulder shows with the slash of \*\*) crosses an optical axis (image formation is carried out) -- it becomes like. Therefore, the 1st flux of light and the 2nd flux of light are condensed near the information recording surface of the 2nd optical disk, and playback of the 2nd optical disk is performed. Although the 3rd flux of light (shown by the broken line to the middle) serves as the flare at this time, it becomes reproducible [ the 2nd optical disk ] by the nucleus formed by the 1st flux of light and the 2nd flux of light.

[0022] Each flux of light which divided this invention so that it might correspond to each optical disk which reproduces the 2nd flux of light which uses for playback of all reproducible optical disks the 1st flux of light which passes near [ where a numerical aperture is small ] the optical axis, and passes outside the 1st parting plane when put in another way, and was divided is used for playback of each optical disk (this example the 1st and 2nd optical disk). Furthermore, the flux of light (this example the 3rd flux of light) which is separated from the 1st flux of light among the divided flux of lights is used for playback of an optical disk with a larger numerical aperture required in order to reproduce the information on an optical disk (this example the 1st optical disk).

[0023] If such optical system (this example objective lens 16) is used, numerical aperture NA2 required for playback of the 2nd optical disk can be enlarged by becoming possible to play two or more disks with which the thickness of a transparence substrate differs by one optical system, and being able to set the diameter of a parting plane as arbitration. Moreover, quantity of light loss of the flux of light from the light source decreases by using the flux of light near the optical axis for playback of two or more optical disks. And at the time of the 2nd optical disk playback, the side lobe of the beam spot is decreased, a nucleus with strong beam reinforcement is formed, and exact information is acquired. Furthermore, two or more disks can be played by one condensing optical system, without needing a special means to change the numerical aperture of diaphragm 17.

[0024] In addition, in this example, although parting planes Sd1-Sd3 and a diffraction side were established in the field S1 by the side of the light source of an objective lens 16, you may prepare in the refracting interface by the side of a disk 20, and such [ one ] a function of the optical elements (for example, collimator lens 13 etc.) of other condensing optical system may be given, and the optical element which still more newly has such a function may be prepared on an optical path. Moreover, it may decompose into a different optical element and the function of each parting planes Sd1-Sd3 may be prepared.

[0025] Moreover, although the so-called objective lens 16 of the infinity system which used the collimator lens 13 was used in this example, there is no collimator lens 13 and you may apply to an objective lens in which the emission light through the lens from which the emission light from the light source subtracts the emission degree of direct or emission light carries out incidence, and an objective lens with which the convergence light carries out incidence of the flux of light from the light source using the coupling lens changed into convergence light.

[0026] Moreover, what is necessary is just to constitute not only from this but from at least three parting planes or more at this example, although the field S1 was constituted from three parting planes Sd1-Sd3. For example, when [ this ] a field S1 is constituted from five parting planes Sd1-Sd5, When the 2nd and 4th parting planes are made into a hologram and numerical aperture of the boundary of NA3, the 4th parting plane, and the 5th parting plane is set to NA4 for the numerical aperture of the boundary of the 3rd parting plane and the 4th parting plane, It is desirable to satisfy the conditions of  $0.60(NA2) < NA3 < 1.3(NA2)$  and  $0.01 < NA4 - NA3 < 0.12$ . The disk of the big need numerical aperture as the 2nd optical disk can be played without this dropping the reinforcement of the optical spot which the 1st disk is made to condense. Furthermore, as for the upper limit of NA3, it is desirable practically that it is  $NA3 < 1.1(NA2)$ , and the minimum of NA3 has desirable  $0.80(NA2) < NA3$ , and it is desirable practically to a pan that it is  $0.85(NA2) < NA3$ . Moreover, as for the upper limit of NA4-NA3, it is desirable that it is  $NA4 - NA3 < 0.1$ .

[0027] Moreover, when an objective lens 16 is seen from the light source, although the hologram of the shape of an annulus of the shape of an optical axis and a concentric circle was prepared, it is not restricted to this but Fresnel may constitute the 2nd parting plane Sd2 from this example. In addition, one side of the flux of light divided into zero-order light and primary light is used for playback of the 1st optical disk, and another side is used for playback of the 2nd optical disk. At this time, the quantity of light of the flux of light used for playback of the 2nd optical disk may be enlarged. Furthermore, although the diffraction side which mainly uses zero-order light and primary light was established, it is good also as a diffraction side which considers as the diffraction side using primary light and secondary light, or uses high order light.

[0028] The best wave aberration by the flux of light which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 in this example in case the 1st disk is played (namely, when the transparence substrate of thickness t1 is minded) Moreover,  $0.05\lambda$  arms It not only fills (however, the wavelength of the light source used in case  $\lambda(\text{nm})$  plays the 1st disk), but Furthermore,  $0.07\lambda$  arms whose best wave aberration by the flux of light which passes the 1st parting plane Sd1 in case the 2nd optical disk is played (namely, when the transparence substrate of thickness t2 is minded) is a diffraction limitation The regenerative signal of the 2nd optical disk can be made good by filling (however, the wavelength of the light source used in case  $\lambda(\text{nm})$  plays the 2nd disk).

[0029] Next, the spherical-aberration Fig. of an objective lens 16 is explained about the 2nd example with reference to drawing 3 which is drawing shown typically. In drawing 3, (a) is the spherical aberration when minding playback, i.e., the transparence substrate of thickness t1, for the 1st disk; and (b) is the spherical aberration when minding playback, i.e., the transparence substrate of thickness t2 (this example  $t2 > t1$ ), for the 2nd disk. The need numerical aperture by the side of the optical disk of condensing optical system required in order to reproduce the information on NA1 and the



2nd optical disk for the need numerical aperture by the side of the optical disk of condensing optical system required here in order to reproduce the information on the 1st optical disk NA2. The numerical aperture by the side of the optical disk of the flux of light which passes through a boundary with the parting planes Sd2 and Sd3 of neuroleptanalgesia and an objective lens 16 the numerical aperture by the side of (however,  $NA2 < NA1$ ) and the optical disk of the flux of light which passes through a boundary with the parting planes Sd1 and Sd2 of an objective lens 16 is set to NAH.

[0030] In addition, the part which, as for the 2nd example, the objective lens 16 indicated as the 1st above-mentioned example is looked at from another viewpoint (spherical aberration, a configuration, wave aberration, etc.), and is not indicated below is the same as that of the above-mentioned example.

[0031] An objective lens 16 like the 1st example, of the above designs the 1st aspheric surface (zona-orbicularis-like parting plane) of the 1st refracting interface S1, and the 2nd refracting interface S2 (common refracting interface) so that the best wave aberration of the flux of light which the thickness of a transparence substrate made the 1st optical disk of t1 condense may become below  $0.05\lambda$  at first. The spherical aberration of the lens obtained by this design is drawing 3 (a). And zero-order light does not affect spherical aberration at the time of the 1st optical disk use, but the 2nd refracting interface S2 (common refracting interface) remains as it is, and designs the 1st diffraction side so that the primary diffracted light may serve as spherical aberration fewer than the yield (drawing 3 (c)) of spherical aberration when the thickness of a transparence substrate makes the 2nd optical disk of t2 ( $t2 \neq t1$ ) condense through the lens which has this 1st aspheric surface. At this time, as for the paraxial radius of curvature of the 1st diffraction side, and the paraxial radius of curvature of the 1st aspheric surface, it is desirable to make it the same in order to play the 2nd optical disk reproduced in the state of defocusing good. The spherical aberration at the time of making the 2nd optical disk of the lens obtained by this design condense is drawing 3 (d), and the aberration Fig. of the lens at the time of making the 1st optical disk condense with this lens is drawing 3 (a). And the 1st diffraction side is compounded with about two need numerical aperture NA of the 2nd optical disk of this 1st aspheric surface.

[0032] therefore, as a field configuration in the refracting interface S1 of this objective lens 16 It becomes the aspheric surface configuration (the 1st aspheric surface) where the 3rd parting plane Sd3 outside the 1st parting plane Sd1 and the 1st parting plane Sd1 including an optical axis is the same. The 2nd parting plane Sd2 between the 1st parting plane Sd1 and 3rd parting plane Sd3 (about two numerical aperture NA required for playback of the 2nd optical disk, i.e., neuroleptanalgesia-NAH) serves as a different field configuration from the 1st parting plane Sd1 and the 3rd parting plane Sd3. The obtained lens turns into the objective lens 16 of this example, the spherical-aberration Fig. at the time of making the 1st optical disk condense using this objective lens 16 serves as drawing 3 (a), and the spherical-aberration Fig. at the time of making the 2nd optical disk condense serves as drawing 3 (b).

[0033] As mentioned above, the objective lenses 16 obtained in this example are at least two opening locations near the numerical aperture NA2 (neuroleptanalgesia and NAH), and they are constituted so that two or more disks with which the thickness of a transparence substrate differs can be played by one condensing optical system, and spherical aberration may change to discontinuity. Thus, since it was made for spherical aberration to change to discontinuity, it is the range of each numerical aperture (in this example, an optical axis - neuroleptanalgesia the 1st parting plane). The flux of light (this example the 1st flux of light - the 3rd flux of light) which passes the 2nd parting plane of NAH and the 3rd parting plane of NAH-NA1 can be constituted from neuroleptanalgesia in arbitration. It becomes possible to use for playback of two or more optical disks of all, that reproduce the 1st flux of light, and to use the 2nd flux of light and the 3rd flux of light for playback of a predetermined optical disk among two or more optical disks, respectively. two or more optical disks by one condensing optical system (this example objective lens 16) -- reproducible -- low cost -- and it can carry out without complicating, and it can respond also to the optical disk of further high NA. And that what is necessary is just to prepare as extracted and corresponded in 17 to NA1 which is high NA, even if numerical aperture required for optical disk playback changes (to NA1 or NA2), it is not necessary to establish at all a means to change diaphragm 17. In addition, when it sees in the spherical-aberration Fig. "from which spherical aberration changes to discontinuity", it says that a rapid change of spherical aberration is seen.

[0034] Furthermore, when the direction which changes to the discontinuity of spherical aberration is seen from small numerical aperture to large numerical aperture, in numerical aperture neuroleptanalgesia, it becomes a negative direction, and spherical aberration has become [ spherical aberration ] a positive direction with numerical aperture NAH. While playback of the optical disk of the thickness t1 of a thin transparence substrate becomes good by this, playback of the optical disk of the thickness t2 of a transparence substrate thicker than this can carry out good. In addition, although spherical aberration changes to a negative direction in numerical aperture neuroleptanalgesia in a positive direction and changes to discontinuity with numerical aperture NAH as mentioned above since it is  $t2 > t1$  and  $NA1 > NA2$  in this example, when it is t1 and  $t2 < NA1 > NA2$ , with numerical aperture NAH, in numerical aperture neuroleptanalgesia, spherical aberration will change to a negative direction in a positive direction, and will change to discontinuity.

[0035] Furthermore, in case the 2nd optical disk of the thickness t2 of a transparence substrate is played, when making

it the spherical aberration (spherical aberration by the flux of light diffracted by the 2nd parting plane Sd2) of a before [ from numerical aperture neuroleptanalgnesia / numerical aperture NAH ] serve as forward, the S characteristics of optical pickup equipment 10 improve. In addition, although it was made for the spherical aberration of a before [ from numerical aperture neuroleptanalgnesia / numerical aperture NAH ] to serve as forward in this example since it was  $t_1$  and  $t_2 < NA_1 > NA_2$ , in  $t_1$  and  $t_2 < NA_1 > NA_2$ , it is good to consider as negative.

[0036] Moreover, the wave aberration of the objective lens 16 of this example is shown in drawing 4. It is the wave aberration curve to which drawing 4 took wave aberration ( $\lambda$ ) along the axis of ordinate, and took the numerical aperture along the axis of abscissa, and (a) expresses wave aberration when (b) minds the transparence substrate (thickness  $t_2$ ) of the 2nd optical disk ~~for the flux of minding the transparence substrate (thickness  $t_1$ ) of the 1st optical disk with the continuous line~~. In addition, this wave aberration measures and obtains wave aberration using an interferometer etc. in the condition of becoming the best wave aberration, when each transparence substrate is minded.

[0037] If the objective lens 16 of this example is seen with a wave aberration curve, wave aberration serves as discontinuity by two with a numerical aperture [ NA ] of about two places (they are specifically neuroleptanalgnesia and NAH), so that drawing 4 (b) may show. Moreover, when it is expressed with the unit (mm) of die length, when the amount of discontinuity of the greatest wave aberration generated into the part used as discontinuity is expressed with the unit (rad) of a phase, it is desirable [ the amount / below  $0.05(NA_2)^2$  (mm) ] to carry out to below  $2\pi\{0.05(NA_2)^2\} / \lambda$  (rad) ( $\lambda$  in however, this case operating wavelength a unit mm). Fluctuation of the wave aberration by wavelength variation becomes large, and it becomes impossible to absorb the variation in the wavelength of semiconductor laser more than by this. Furthermore, the inclination of the wave aberration of the part (between neuroleptanalgnesia and NAH(s)) of this discontinuity differs from the inclination of the curve (broken line of drawing 4 (a)) which connects the edge of the curve of the both sides of the part used as discontinuity. In addition, although parting planes Sd1-SD3 were formed in the field S1 by the side of the light source of an objective lens 16 in this example, you may prepare in the refracting interface by the side of an optical disk 20.

[0038] Moreover, although the so-called objective lens 16 of the infinity system which used the collimator lens 13 was used in this example, it is good also by objective lens in which the emission light through the lens from which there is no collimator lens 13 and the emission light from the light source subtracts the emission degree of direct or emission light carries out incidence, and objective lens with which the convergence light carries out incidence of the flux of light from the light source using the coupling lens changed into convergence light.

[0039] In this example, in case the 1st aspheric surface is designed The best wave aberration by the flux of light which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 when the transparence substrate of thickness  $t_1$  is minded as mentioned above  $0.05\lambda$  (However, wavelength of the light source used in case  $\lambda$  (nm) plays the 1st disk) It not only considers as the following, but  $0.07\lambda$  whose best wave aberration by the flux of light which passes the 1st parting plane Sd1 when the transparence substrate of thickness  $t_2$  is minded is a diffraction limitation The 2nd optical disk regenerative signal can be made good by designing so that (however, the wavelength of the light source used in case  $\lambda$  (nm) plays the 2nd disk) may be filled.

[0040] Next, the example in the optical pickup equipment which has the two light sources from which wavelength differs is shown. Although the optical pickup equipment of drawing 5 used the one light source 111, the optical pickup equipment 10 shown in drawing 6 uses two of the light sources 111 and 112. The same sign shows the same component as the component in drawing 5. For playback of the 1st optical disk, it has the 2nd semiconductor laser 112 (wavelength  $\lambda_{112}=740\text{nm}-870\text{nm}$ ) which is the 2nd light source in the 1st semiconductor laser 111 (wavelength  $\lambda_{111}=610\text{nm}-670\text{nm}$ ) which is the 1st light source, and playback of the 2nd optical disk. Moreover, the synthetic means 19 is a means which can compound the flux of light by which outgoing radiation was carried out from the 1st semiconductor laser 111, and the flux of light by which outgoing radiation was carried out from the 2nd semiconductor laser 112, and in order that it may make an optical disk 20 condense both the flux of lights through one condensing optical system, it is a means made into the same optical path.

[0041] First, when playing the 1st disk, outgoing radiation of the beam is carried out from the 1st semiconductor laser 111, and the flux of light by which outgoing radiation was carried out penetrates the synthetic means 19, a polarization beam splitter 12, a collimator lens 13, and the quarter-wave length plate 14, and turns into the parallel flux of light of the circular polarization of light. A rat tail is minded according to diaphragm 17, it minds the transparence substrate 21 of the 1st optical disk 20 with an objective lens 16, and this flux of light is condensed on the information recording surface 22. And the flux of light which the information pit became irregular and was reflected by the information recording surface 22 penetrates an objective lens 16, the quarter-wave length plate 14, and a collimator lens 13 again, and they carry out incidence to a polarization beam splitter 12, and it reflects here, astigmatism is given by the cylindrical lens 18, incidence is carried out to up to a photodetector 30, and the reading signal of the information recorded on the 1st optical disk 20 using the signal outputted from a photodetector 30 is acquired. Moreover, the quantity of light distribution change by the formation of a form status change of the spot on a photodetector 30 is

detected, and focus detection and track detection are performed. While moving an objective lens 16 in the direction of an optical axis so that the two-dimensional actuator 15 may carry out image formation of the flux of light from semiconductor laser 111 on the information recording surface 22 of the 1st optical disk based on this detection, an objective lens 16 is moved in the direction perpendicular to an optical axis so that image formation of the flux of light may be carried out to a predetermined track.

[0042] On the other hand, when playing the 2nd disk, outgoing radiation of the beam is carried out from the 2nd semiconductor laser 112, and the flux of light by which outgoing radiation was carried out has an optical path changed by the synthetic means 19, and is condensed on the 2nd optical disk 20 after that through a polarization beam splitter 12, a collimator lens 13, the quarter-wave length plate 14, diaphragm 17, and an objective lens 16. And incidence of the flux of light which the information pit became irregular and was reflected by the information recording surface 22 is again carried out to up to a photodetector 30 through an objective lens 16, the quarter-wave length plate 14, a collimator lens 13, a polarization beam splitter 12, and a cylindrical lens 18, and the reading signal of the information recorded on the 2nd optical disk 20 using the signal outputted from a photodetector 30 is acquired. Moreover, the quantity of light distribution change by the formation of a form status change of the spot on a photodetector 30 is detected, and focus detection and track detection are performed. While moving an objective lens 16 in the direction of an optical axis so that the two-dimensional actuator 15 may carry out image formation of the flux of light from semiconductor laser 112 in the state of defocusing on the information recording surface 22 of the 1st optical disk based on this detection, an objective lens 16 is moved in the direction perpendicular to an optical axis so that image formation of the flux of light may be carried out to a predetermined track.

[0043] An objective lens like a previous example is used for the objective lens 16 which is one of the condensing optical system of such optical pickup equipment 10. That is, it is the convex lens with which an objective lens 16 has the forward refractive power which both the field S1 by the side of the light source and the refracting interface S2 by the side of an optical disk presented the aspheric surface configuration, and the field S1 by the side of the light source consists of the 1st parting plane Sd1 of plurality (this example three) - the 3rd parting plane Sd3 on an optical axis and this alignment, and the boundary of parting planes Sd1-Sd3 prepares a level difference. And the 1st parting plane Sd1 and the 3rd parting plane Sd3 It forms in the 1st aspheric surface where the best wave aberration of the flux of light which outgoing radiation was carried out [ wave aberration ] from the 1st light source 111, and made the 1st optical disk condense becomes below  $0.05\lambda$  rms. Moreover, the 2nd parting plane It forms in respect of diffraction so that it may become spherical aberration fewer than the yield of spherical aberration when the thickness of a transparency substrate makes the 2nd optical disk of  $t_2$  ( $t_2 \neq t_1$ ) condense the flux of light of the 2nd light source 112 through the lens which has the 1st aspheric surface. It considers as the objective lens which compounded the diffraction side to neuroleptanalgesia-NAH which is about two need numerical aperture NA of the 2nd optical disk of this 1st aspheric surface. Since the obtained objective lens 16 will have the same configuration as a previous example, an operation, and effectiveness except for the following points and the two light sources are used further, it faces playing two or more optical disks, and a degree of freedom becomes large.

[0044] In this example, since the two light sources 111 and 112 are used, the following desirable range differs from a previous example. namely,  $t_1 = 0.6\text{mm}$   $t_2 = 1.2\text{mm}$  and  $1 < 670\text{nm}$  of  $610\text{nm} < \lambda_1 < 870\text{nm}$  of  $740\text{nm} < \lambda_2$ , and  $0.4 < \text{NA}_1 < 0.8$  it is desirable to fulfill the conditions (for 0.80 (NA2) to be desirable practically as for this minimum 0.60 (NA2), and it to be desirable that it is further 0.85 (NA2).) of  $0.60(\text{NA}_2) < \text{neuroleptanalgesia} < 1.1(\text{NA}_2)$  to set to  $\text{NA}_2 < 0.51$ . If this minimum is exceeded, a side lobe will become large, informational exact playback cannot be performed, but if an upper limit is exceeded, it will be extracted too much more than the diameter of a diffraction marginal spot assumed in wavelength  $\lambda_2$  and NA2. In addition, neuroleptanalgesia as used in the field of here points out neuroleptanalgesia on the 2nd parting plane Sd2 when using the 2nd light source 112.

[0045] Moreover, it is desirable to fulfill the conditions of  $0.01 < \text{NAH-neuroleptanalgesia} < 0.12$  (as for this upper limit 0.12, it is still more desirable practically that it is 0.1). If this minimum is exceeded, the spot configuration at the time of playback of the 2nd optical disk will get worse, and if the diameter of a side-lobe spot becomes large and exceeds an upper limit, the spot configuration at the time of playback of the 1st optical disk will cause turbulence and a quantity of light fall. In addition, NAH here and neuroleptanalgesia point out NAH and neuroleptanalgesia on the 2nd parting plane Sd2 when using the 2nd light source 112.

[0046] Moreover, it is desirable that the spherical aberration between numerical aperture neuroleptanalgesia and numerical aperture NAH fulfills  $-2(\lambda_2/(\text{NA}_2)^2)$  or more and  $5(\lambda_2/(\text{NA}_2)^2)$  or less conditions at the time of playback of the 2nd optical disk (when the transparency substrate of the thickness of  $t_2$  is minded). Furthermore, it is desirable that this condition is larger than 0 (zero) if  $3(\lambda_2/(\text{NA}_2)^2)$  or less is desirable in playback or record, is also taken into consideration (playback is also possible, of course.). If spherical aberration will amend too much, the spot configuration at the time of the 1st optical disk playback of a next door will get worse, if this minimum is exceeded, and an upper limit is exceeded, the spot configuration at the time of playback of the 2nd optical disk will get

worse, and the diameter of a side-lobe spot will become large. As for especially this condition, it is still more desirable to satisfy the range of  $0 - 2 (\lambda/2)/(\text{NA}^2)^2$ , and a focal error signal is obtained good in this case.

[0047] Moreover, when it sees from another viewpoint, they are the conditions (as for this minimum 0.60 (NA2), 0.80 (NA2) is desirable practically) of  $0.60(\text{NA}^2) < \text{NA}^3 < 1.1 (\text{NA}^2)$ . It is desirable that it is further 0.85 (NA2). While it is satisfied, between the numerical aperture NA3 by the side of the optical disk of the objective lens 16 with which are satisfied of the conditions of  $0.01 < \text{NA}^4 - \text{NA}^3 < 0.12$  (preferably 0.1), and numerical aperture NA4 neuroleptanalgesia and NAH which were mentioned above are prepared (that is, the parting plane mainly used for playback of the 2nd optical disk is prepared.). They are things. The optical disk of the big need numerical aperture as the 2nd optical disk can be played without this dropping the reinforcement of the optical spot which the 1st optical disk is made to condense.

[0048] Especially, by  $t_2 > t_1$  and  $\text{NA}^1 > \text{NA}^2$ , when it sees from an optical axis to a circumferential direction, in numerical aperture neuroleptanalgesia, the intersection of the normal of a refracting interface and an optical axis changes to discontinuity in the direction approaching the refracting interface by the side of the light source, and it is changing to discontinuity with numerical aperture NAH in the direction in which the intersection of the normal of a refracting interface and an optical axis gets away from the refracting interface by the side of the light source. While playback of the optical disk of the thickness  $t_1$  of a thin transparence substrate becomes good by this, playback of the optical disk of the thickness  $t_2$  of a transparence substrate thicker than this can carry out good.

[0049] Moreover, it sets to the objective lens 16 which has two or more parting planes (this example three parting planes) divided an optical axis and in the shape of a solid alignment in one [ at least ] field like a previous example when this example is seen from another viewpoint. When it is made for the light which penetrated the 1st parting plane Sd1, and the light which penetrated the 3rd parting plane Sd3 to serve as the almost same phase through the transparence substrate of predetermined thickness (the 1st optical disk), The light which penetrated the 1st parting plane Sd1 and minded the transparence substrate, and the light of the 2nd parting plane Sd2 which penetrated the 2nd parting plane Sd2 by the side of an optical axis, and minded the transparence substrate from the mid gear mostly, \*\* -- about -- phase reference --  $\pi$  (\*\*1L) (rad) -- \*\* -- carrying out -- the -- three -- a parting plane -- Sd -- three -- penetrating -- transparence -- a substrate -- having minded -- light -- said -- a mid gear -- an optical axis -- a side -- the opposite side -- the -- two -- a parting plane -- Sd -- two -- penetrating -- transparence -- a substrate -- having minded -- light -- \*\* -- phase contrast --  $\pi$  (\*\*1H) (rad) -- \*\* -- carrying out -- if --  $> (\pi/2)$  (\*\*1H) (\*\*1L) -- being satisfied . this case -- the above -- the same -- the case of  $t_1 > t_2$  and  $\text{NA}^1 > \text{NA}^2$  --  $< (\pi/2)$  (\*\*1H) (\*\*1L) -- \*\* -- it carries out. Therefore, it considers as  $\neq (\pi/2)$  (\*\*1L).

[0050] In addition, it is not restricted to the description about this examples, such as forming parting planes Sd1-Sd3 in the refracting interface S1 of an objective lens 16, using the objective lens of an infinity system, preparing a level difference in a parting plane, the number of parting planes, and a field configuration of the 2nd parting plane, like a previous example. Moreover, although the 1st light source 111 and the 2nd light source 112 were compounded with the synthetic means 19, it is not restricted to this but the light source 11 may be made to change to the 1st light source 111 and the 2nd light source 112 in the optical pickup equipment shown in drawing 1.

[0051] Moreover, when the 1st optical disk is played in this example () The best wave aberration by the flux of light which passes the 1st parting plane Sd1 and the 3rd parting plane Sd3 when the transparence substrate of thickness  $t_1$  is minded Namely,  $0.05\lambda$  It not only fills (however, the wavelength of the light source used in case  $\lambda(\text{nm})$  plays the 1st optical disk), but Furthermore,  $0.07\lambda$  whose best wave aberration by the flux of light which passes the 1st parting plane Sd1 in case the 2nd optical disk is played (namely, when the transparence substrate of thickness  $t_2$  is minded) is a diffraction limitation The regenerative signal of the 2nd optical disk can be made good by filling (however, the wavelength of the light source used in case  $\lambda(\text{nm})$  plays the 2nd optical disk).

[0052] In addition, when this applicant for a patent used for the optical pickup equipment shown in a previous example, playback of CD as the 2nd optical disk was also possible in the objective lens 16 in this example, at the light source of the same wavelength not to mention playback of DVD as the 1st optical disk. The light source of wavelength  $\lambda_1$  is used for the objective lens 16 of this example. The thickness of the 1st light information record medium of  $t_1$  and a transparence substrate Namely,  $t_2$  [ the thickness of a transparence substrate ] While being able to make it condense on the information recording surface of the 2nd light information record medium of ( $t_2 \neq t_1$  [ however, ]), even if it is the case where the light source of wavelength  $\lambda_2$  (however,  $\lambda_2 \neq \lambda_1$ ) is used, it can condense on the information recording surface of the 2nd light information record medium. The objective lens used for the optical pickup equipment (it corresponds to the light source with a wavelength of 610nm - 670nm and the light source with an indispensable to CD-R wavelength of 780nm for DVD) which sets playback of CD-R to DVD by this using the two light sources from which wavelength differs, The objective lens used for the optical pickup equipment (it corresponds to the light source with a wavelength of 610nm - 670nm) which carries out playback of DVD or CD by the one light source can be communalized, and low cost-ization accompanying mass production method can be realized. In addition,

that it can communalize in this way needs to satisfy neuroleptanalgesia indicated in the previous example, and the conditions of NAH, even if the wavelength of the light source changed into  $\lambda_1$  from  $\lambda_2$ .

[0053] In addition, in this example, although it can consider as one photodetector 30 and a configuration can be simplified since the 1st light source 111 and the 2nd light source 112 are used for the almost same scale factor, it may be made to correspond to each light sources 111 and 112, two photodetectors may be formed, and a scale factor may be changed further.

[0054] Hereafter, the lens data of one example at the time of applying this invention to the refracting interface by the side of the light source of an objective lens 16 are shown. DVD (thickness  $t_1=0.6\text{mm}$  of a transparence substrate, required numerical aperture  $\text{NA}_1=0.60$  ( $\lambda=635\text{nm}$ )) is used as the 1st optical disk, as the 2nd optical disk -- CD (thickness  $t_2=1.2\text{mm}$ , required numerical aperture  $\text{NA}_2=0.366$  ( $\lambda=635\text{nm}$ ), or  $\text{NA}_2=0.45$  ( $\lambda=780\text{nm}$ )) of a transparence substrate), or CD-R (thickness [ of a transparence substrate ]  $t_2=1.2\text{mm}$ ) Required numerical aperture  $\text{NA}_2=0.50$  ( $\lambda=780\text{nm}$ ) (in however, the case only of playback  $\text{NA}_2=0.45$  ( $\lambda=780\text{nm}$ )) will be used. In addition, in the example of the following objective lenses 16, since a collimator lens 13 can carry out incidence of the parallel flux of light of non-aberration mostly to an objective lens 16 by making a design the optimal, after the parallel flux of light carries out incidence to an objective lens 16 in the following examples, a configuration is shown. The diaphragm arranged at the light source side of an objective lens 16 is made into the 1st page. The radius of curvature of the  $i$ -th lens side sequentially from here Moreover,  $r_i$ , It is  $d_i$  (at the time of CD playback, when unstated [ changing to the numeric value, when  $d_i$  has a publication and ], it is the same as  $d_i$ .) about the distance between the  $i$ -th field at the time of DVD playback, and the  $i+1$ st fields. The refractive index in the wavelength of the flux of light of the laser light source of the spacing is expressed with  $n_i$ . Moreover, when the aspheric surface is used for an optical surface, it shall be based on the formula of the aspheric surface mentioned above.

[0055] (Example 1) An example 1 is the objective lens 16 carried in the optical pickup equipment 10 of the 1 light source of the previous example mentioned above, and is an example which carried out this invention to the objective lens 16 which prepared the level difference in the boundary of the 1st parting plane  $Sd_1$  - the 3rd parting plane  $Sd_3$ . In this example, the aspheric surface shall be based on a degree type.

[Equation 1]

$$X = \frac{H^2 / r}{1 + \sqrt{1 - (1 + \kappa) (H/r)^2}} + \sum_j A_j H^{P_j}$$

However,  $X$  sets the shaft of the direction of an optical axis as an optical axis, a vertical shaft, and the travelling direction of light,  $H$  considers as forward, and, for  $r$ , paraxial radius of curvature and  $\kappa$  are [ an aspheric surface multiplier and  $P_j$  of a cone number and  $A_j$  ] the numbers of \*\*\*\* of the aspheric surface (however,  $P_j \geq 3$ ). In addition, the formula of other aspheric surfaces other than an upper type may be used. In case it asks for the formula of the aspheric surface from an aspheric surface configuration, using an upper type,  $P_j$  is made into the natural number of 10  $\geq P_j \geq 3$ , and it asks as  $\kappa = 0$ . Moreover, the 1st diffraction side shall be expressed as a thin film of a high refractive index. an optical-path-difference function --  $\phi(h) = C_1 h^2 + C_2 h^4 + C_3 h^6 + C_4 h^8 + C_5 h^{10}$  -- expressing -- the amount of shaving from a substrate side --  $L = \{\phi(h) + i\lambda\} / (n-1)$   $i = 0$ , and 1 and 2 -- it is ...

[0056]

[Table 2]

Wavelength 650nm 780nm A focal distance 3.36 3.39 The diameter of drawing  $\phi = 4.04\text{mm}$  Objective lens lateral magnification 0  $i$   $r_i$   $d_i$   $d_i'$   $n_i$  1 infinity 0 1 1 2 2.114 2.2 1.5377 1.5337 3 -7.963 1.757 1 1 4 infinity 0.6 1.2 1.58 1.58 5 infinity [Table 3]

Aspheric surface data The 2nd page Aspheric surface section  $0 \leq H \leq 1.321$  (the 1st parting plane)

$1.532 \leq H$  (the 3rd parting plane)

(Aspheric surface multiplier)  $\kappa = [-1.1372]$   $A_1 = -0.30074 \times 10^{-3}$   $P_1 = 3.0$   $A_2 = 0.43633 \times 10^{-2}$   $P_2 = 4.0$   $A_3 = 0.79005 \times 10^{-2}$   $P_3 = 5.0$   $A_4 = -0.49422 \times 10^{-2}$   $P_4 = 6.0$   $A_5 = 0.12018 \times 10^{-2}$   $P_5 = 7.0$   $A_6 = 0.25012 \times 10^{-4}$   $P_6 = 8.0$   $A_7 = -0.18446 \times 10^{-4}$   $P_7 = 10.0$  Hologram section  $1.321 \leq H \leq 1.532$  (the 2nd parting plane)

(Aspheric surface multiplier)  $\kappa = [-1.1372]$   $A_1 = -0.30074 \times 10^{-3}$   $P_1 = 3.0$   $A_2 = 0.43633 \times 10^{-2}$   $P_2 = 4.0$   $A_3 = 0.79005 \times 10^{-2}$   $P_3 = 5.0$   $A_4 = -0.49422 \times 10^{-2}$   $P_4 = 6.0$   $A_5 = 0.12018 \times 10^{-2}$   $P_5 = 7.0$   $A_6 = 0.25012 \times 10^{-4}$   $P_6 = 8.0$   $A_7 = -0.18446 \times 10^{-4}$   $P_7 = 10.0$  (optical-path-difference multiplier)  $C_1 = -0.10423 \times 10^{-3}$   $C_2 = 0.25757 \times 10^{-3}$   $C_3 = -0.20235 \times 10^{-3}$   $C_4 = 0.44453 \times 10^{-4}$   $C_5 = -0.39336 \times 10^{-5}$  The 3rd page (aspheric surface multiplier)  $\kappa = -0.23984 \times 10^2$   $A_1 = -0.25083 \times 10^{-2}$   $P_1 = 3.0$   $A_2 = 0.10598 \times 10^{-1}$   $P_2 = 4.0$   $A_3 = 0.45136 \times 10^{-2}$   $P_3 = 5.0$   $A_4 = -0.72617 \times 10^{-2}$   $P_4 = 6.0$   $A_5 = -0.15133 \times 10^{-3}$   $P_5 = 7.0$   $A_6 = 0.13381 \times 10^{-2}$   $P_6 = 8.0$   $A_7 = -0.1111 \times 10^{-3}$   $P_7 = 10.0$  [0057] Moreover, the spherical-

aberration Fig. (henceforth the time of CD playback) when minding the transparence substrate of thickness  $t_2$  ( $= 1.2\text{mm}$ ) for the spherical-aberration Fig. (henceforth the time of DVD playback) when minding the transparence substrate of thickness  $t_1$  ( $= 0.6\text{mm}$ ) (a) (b) is shown. Moreover, the wave aberration Fig. when seeing the wave aberration Fig. when seeing in the condition of having defocused in the location where the best wave aberration at the

time of DVD playback is obtained by drawing 4 (a) in the condition of having defocused in the location where the best wave aberration at the time of CD playback is obtained by drawing 4 (b) is shown. The amount of wave aberration within  $0.025\lambda$  and the 1st paring plane at the time of CD use of the amount of wave aberration of NA1 at the time of DVD use is  $0.054\lambda$ . Moreover, the relative intensity distribution map of a condensing spot when the best spot configuration at the time of DVD playback is acquired by drawing 7 (a) is shown, and the relative intensity distribution map of a condensing spot when the best spot configuration is acquired by drawing 7 (b) at the time of CD playback is shown.

[0058]

[Effect of the Invention] it explained in full detail above -- as -- this invention -- setting -- record playback of two or more optical information record media by one condensing optical system -- it can do -- low cost -- and it can realize without complicating, and it can respond also to the optical information record medium of further high NA. Furthermore, in this invention, generating of spherical aberration can be used positively and one condensing optical system can perform record playback of two or more optical information record media.

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[Translation done.]



**\* NOTICES \***

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1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

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**DESCRIPTION OF DRAWINGS**

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**[Brief Description of the Drawings]**

[Drawing 1] It is the cross section of the objective lens for optical pickup equipments of this invention, and the focusing situation to the 1st light information record medium is shown.

[Drawing 2] It is the cross section of the objective lens for optical pickup equipments of this invention, and the focusing situation to the 2nd light information record medium is shown.

[Drawing 3] It is the explanatory view showing the amendment situation of the spherical aberration of each parting plane of the objective lens of this invention.

[Drawing 4] It is the aberration Fig. showing the amendment situation of the wave aberration of each parting plane of the objective lens of this invention.

[Drawing 5] It is the conceptual diagram showing an example of the configuration of optical pickup equipment which carries out this invention.

[Drawing 6] It is the conceptual diagram showing other examples of the configuration of the optical pickup equipment which carries out this invention.

[Drawing 7] It is the graph which shows relative intensity distribution of the objective lens of this invention of the best spot configuration.

**[Description of Notations]**

11 Semiconductor Laser 12 Deviation Beam Splitter  
 13 Collimator Lens 14  $1/4\lambda$  Plate  
 15 Actuator 16 Objective Lens  
 17 Drawing 18 Cylindrical Lens  
 19 Flux of Light Composition Means 20 Optical Disk  
 21 Transparence Version 22 Information Recording Surface  
 30 Photodetector

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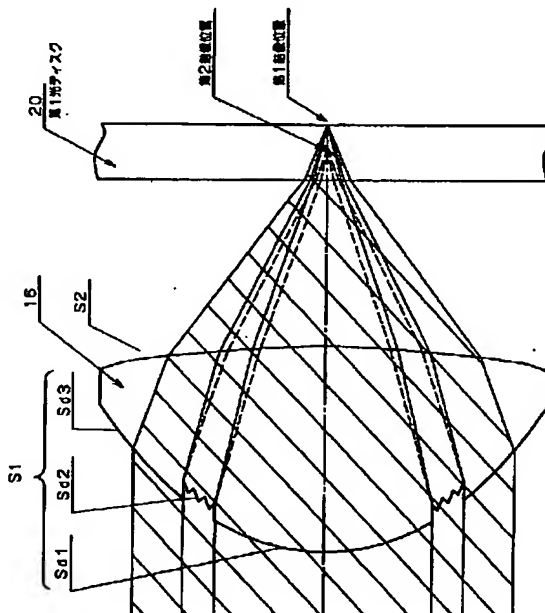
EC45 JA44 JB02

(54)【発明の名称】 光情報記録媒体の記録再生用光ピックアップ装置、対物レンズ及び対物レンズの設計方法

#### (57)【要約】

【課題】 1つの集光光学系で複数の光ディスクを再生出来、低コストかつ複雑化しないで実現でき、さらに、高NAの光ディスクにも対応できることを目的とする。

【解決手段】 光ピックアップ装置10の対物レンズ16の光源側の屈折面S1に3つの分割面Sd1～Sd3を設け、かつ、第2分割面Sd2を回折面とする。透明基板の厚さが $t_1$ の第1光ディスク再生の際には第1分割面Sd1および第3分割面Sd3を通過する光束および第2分割面Sd2での0次光を利用し、透明基板の厚さが $t_2$  ( $t_2 \neq t_1$ )の第2光ディスクの再生の際には第1分割面Sd1を通過する光束および第2分割面での1次光を利用する。



## 【特許請求の範囲】

【請求項1】 透明基板の厚さが $t_1$ の第1光情報記録媒体と透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体とに対して、光源から出射した光束を1つの集光光学系で透明基板を介して情報記録面に集光させ、情報記録面上に情報を記録し再生する光ピックアップ装置において、

上記集光光学系を構成する少なくとも1つの光学面を、該光学面の中央に位置する光軸近傍の第1分割面と、該第1分割面との間に第2分割面を挟んで位置する第3分割面とに分割された光学面で構成し、

透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生の際には上記第1分割面および第3分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成し、

透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体の記録再生の際には上記第1分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成し、

上記第2分割面の光軸側縁を通る光束の光情報記録媒体側の開口数が0.35以上であることを特徴とする光ピックアップ装置

【請求項2】 透明基板の厚さが異なる複数の光情報記録媒体に、波長 $\lambda$ の光源から出射した光束を集光させる光ピックアップ装置の対物レンズの設計方法において、透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生に必要な対物レンズの光情報記録媒体側の開口数 $NA_1$ の範囲内において、厚さ $t_1$ の透明基板を介して第1光情報記録媒体に集光させた光束の最良波面収差が、0.05 $\lambda$  rms以下となるように第1非球面と共通屈折面とを設計すると共に、

透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体に1次光により集光させた光束の球面収差の発生量が、第2の光情報記録媒体に第1非球面を介して集光させたときの球面収差の発生量より少なくなるように、前記共通屈折面に対する第1回折面を、その光軸側縁の開口数が0.35以上であるように設計し、

これら第1非球面と第1回折面とを、上記第2光情報記録媒体の記録再生に必要な対物レンズの情報記録面側の開口数を $NA_2$ （ただし、 $NA_2 < NA_1$ ）としたとき、上記第1非球面の上記 $NA_2$ 近傍の光束が通過する部分に上記第1回折面が位置するように合成することにより、上記対物レンズの少なくとも1つの面を設計することを特徴とする対物レンズの設計方法

【請求項3】 上記第1非球面の軸上曲率半径と、上記第1回折面の軸上曲率半径とを同一として設計することを特徴とする請求項2の対物レンズの設計方法

【請求項4】 上記第1非球面は、合成する第1回折面よりも光軸側に位置する第1非球面を通過し、透明基板の厚さが $t_2$ の第2光情報記録媒体に集光させた光束の

最良波面収差が0.07 $\lambda$  rms以下であるように設計することを特徴とする請求項2または3の対物レンズ

【請求項5】 透明基板の厚さが異なる複数の光情報記録媒体に、光源から出射した光束を集光させる対物レンズにおいて、

少なくともその1つの屈折面を、

透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生に必要な対物レンズの光情報記録媒体側の開口数 $NA_1$ の範囲内において、厚さ $t_1$ の透明基板を介して集光させた光束の最良波面収差が0.05 $\lambda$  rms以下となるような第1非球面と、

透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体に集光させた光束の球面収差の発生量が、第2光情報記録媒体上に上記第1非球面を介して集光させたときの球面収差の発生量より少なくなるような第1回折面とを上記第1非球面の $NA_2$ 近傍の光束が通過する部分に前記第1回折面が位置するように合成した面で構成したことを特徴とする対物レンズ

ただし、 $NA_2$ は、上記第2光情報記録媒体の記録再生に必要な対物レンズの情報記録面側の開口数（ $NA_2 < NA_1$ ）である。

【請求項6】 透明基板の厚さが $t_1$ の第1光情報記録媒体と透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体とに対して、光源から出射した光束を1つの集光光学系で透明基板を介して情報記録面に集光させ、情報の記録再生を行なう光ピックアップ装置の対物レンズにおいて、

上記対物レンズは、少なくともその1面が、光軸近傍の第1分割面から順に第2 $n+1$ （ただし $n$ は自然数）分割面まで分割されており、

上記第1分割面を通過する第1光束は、第1光情報記録媒体の記録再生および第2光情報記録媒体の記録再生に利用すると共に、

偶数分割面を通過する光束は第1光情報記録媒体の記録再生および第2光情報記録媒体の記録再生に利用し、第1分割面を除く奇数分割面を通過する光束は主に第1光情報記録媒体の記録再生に利用することを特徴とする光ピックアップ装置の対物レンズ

【請求項7】 光情報記録媒体上に情報を記録再生するために、光情報記録媒体の情報記録面上に光源からの光束を光情報記録媒体の透明基板を介して光スポットとして集光させる光ピックアップ装置の対物レンズにおいて、

波長 $\lambda_1$ の光源を用いて透明基板の厚さが $t_1$ の第1光情報記録媒体および透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体の情報記録面上に集光させることができるとともに、波長 $\lambda_2$ （ただし、 $\lambda_2 \neq \lambda_1$ ）の光源を用いた場合であっても第2光情報記録媒体の情報記録面上に集光することが可能なように、上記対物レンズの少なくとも1面を複数の分割面で構成

し、かつ、上記分割面の少なくとも1つを回折面とし、その光軸側縁の開口数が0.35以上であるようにしたことを特徴とする光ピックアップ装置の対物レンズ

#### 【発明の詳細な説明】

#### 【0001】

【産業上の利用分野】本発明は光源から出射した光束を集光光学系で情報記録面に集光させ、光情報記録媒体上に情報を記録再生する光情報記録媒体の記録再生方法、該方法を実施するための光ピックアップ装置及びその対物レンズ、ならびに該対物レンズの設計方法に関する。

#### 【0002】

【従来の技術】近年、短波長赤色半導体レーザーの実用化に伴い、従来の光情報記録媒体（光ディスクとも云う）であるCD（コンパクトディスク）と同程度の大きさで\*

\*大容量化させた高密度の光情報記録媒体であるDVDの開発がなされた。このDVDでは、635nmの短波長半導体レーザーを使用したときの対物レンズの光ディスク側の開口数NAを0.6としている。なお、DVDは、トラックピッチ0.74μm、最短ビット長0.4μmであり、CDのトラックピッチ1.6μm、最短ビット長0.83μmに対して半分以上に高密度化されている。また、上述したCD、DVDの他に、種々の規格の光ディスク、例えばCD-R（追記型コンパクトディスク）LD（レーザーディスク）MD（ミニディスク）MO（光磁気ディスク）なども商品化されて普及している。表1に種々の光ディスクの透明基板の厚さと、必要開口数を示す。

【表1】

光ディスク	透明基板厚 (mm)	必要開口数NA (光源波長λnm)
CD, CD-R (再生)	1.20	0.45 (λ=780)
CD-R (記録、再生)	1.20	0.50 (λ=780)
LD	1.25	0.50 (λ=780)
MD	1.20	0.45 (λ=780)
MO (3.5インチ, 230MB)	1.20	0.55 (λ=780)
MO (3.5インチ, 640MB)	1.20	0.55 (λ=680)
DVD	0.60	0.60 (λ=635)

【0003】上記光情報記録媒体中、CD-Rについては光源波長λ=780nmである必要があるが、他の光ディスクにおいては、表1に記載した光源波長以外の波長の光源を使用することが出来、使用する波長に応じて必要開口数が変わり、例えば、CDの場合は必要開口数 $NA = \lambda (\mu m) / 1.73$ 、DVDの場合は必要開口数 $NA = \lambda (\mu m) / 1.06$ で近似されることはよく知られている。

【0004】このように、サイズ、基板厚、記録密度、使用波長などが種々異なる様々な光ディスクに対応するため、異なる光ディスクそれぞれに対応した集光光学系を備え、記録再生する光ディスクにより集光光学系を切替る光ピックアップ装置が提案されている。しかし、この光ピックアップ装置では、集光光学系が複数必要となり、コスト高を招くばかりでなく、集光光学系を切替るための駆動機構が必要となり装置が複雑化し、その切替精度も要求されると云う問題がある。

【0005】そこで、1つの集光光学系によって複数の光ディスクを記録再生する光ピックアップ装置が種々提案されている。その1つとして特開平7-302437号公報には、対物レンズの屈折面をリング状の複数領域に分割し、各々の分割面が厚さの異なる光ディスクのうちの1つにビームを結像させることにより、記録再生する光ピックアップ装置が開示されている。

【0006】また、特開平7-57271号公報には、透明基板の厚さがt1の第1の光ディスクのときには、集光されるビームの有する波面収差が0.07λ以下とな\*

※るように設計した対物レンズを用い、透明基板の厚さがt2の第2光ディスクのときには少しデフォーカスした状態で集光スポットを形成する光ピックアップ装置が開示されている。

#### 【0007】

【発明が解決しようとする課題】しかしながら、特開平7-302437号公報開示の光ピックアップ装置は、1つの対物レンズで2つの焦点に入射光量を分割するため、レーザー出力を大きくする必要があり、コスト高を招く。また、特開平7-57271号公報開示の光ピックアップ装置は、第2光ディスク記録再生時にはサイドローブによるジッターの増加が起こる。特に、第1の光ディスクで波面収差が0.07λ以下とされた対物レンズで、第2光ディスクをむりやり記録再生しているため、第2光ディスクの記録再生可能な開口数には限界が生じる。

【0008】本発明は、1つの集光光学系で複数の光情報記録媒体を記録再生出来、低コストかつ簡素な構成で実現でき、さらに、高NAの光情報記録媒体にも対応できる光情報記録媒体の記録再生方法、該方法を実施するための光ピックアップ装置および該ピックアップ装置のための対物レンズを得ることを目的とする。

#### 【0009】

【課題を解決するための手段】本発明の光ピックアップ装置は、透明基板の厚さがt1の第1光情報記録媒体と透明基板の厚さがt2（ただし、 $t2 \neq t1$ ）の第2光情報記録媒体とに対して、光源から出射した光束を1つ

の集光光学系で透明基板を介して情報記録面に集光させ、情報記録面上に情報を記録し再生する光ピックアップ装置において、上記集光光学系を構成する少なくとも1つの光学面を、該光学面の中央に位置する光軸近傍の第1分割面と、該第1分割面との間に第2分割面を挟んで位置する第3分割面とに分割された光学面で構成し、透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生の際には上記第1分割面および第3分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成し、透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体の記録再生の際には上記第1分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成し、その光軸側縁を通る光束の開口数が0.35以上であるようにしたことを特徴とする。

【0010】上記の記録再生方法を実施するための光ピックアップ装置において、上記集光光学系は、集光光学系を構成する少なくとも1つの光学面が、光軸近傍の第1分割面から順に第 $2n+1$ （ただし $n$ は自然数）分割面まで分割することが出来、上記第1分割面を通過する第1光束は、第1光情報記録媒体の記録再生および第2光情報記録媒体の記録再生に利用すると共に、偶数分割面を通過する光束は第1光情報記録媒体の記録再生および第2光情報記録媒体の記録再生に利用し、第1分割面を除く奇数分割面を通過する光束は主に第1光情報記録媒体の記録再生に利用する

【0011】

【発明の実施の形態】上記の分割面は、対物レンズに設けることが出来、光学面の中央に位置する光軸近傍の第1分割面と、該第1分割面との間に第2分割面を挟んで位置する第3分割面とに分割された光学面で構成し、透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生の際には上記第1分割面および第3分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成し、透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体の記録再生の際には上記第1分割面を通過した光束および第2分割面で回折された光束によりビームスポットを形成するようにすることが出来る。

【0012】このとき、対物レンズは、透明基板の厚さが $t_1$ の第1光情報記録媒体の記録再生に必要な光情報記録媒体側の開口数 $NA_1$ の範囲内において、厚さ $t_1$ の透明基板を介して第1光情報記録媒体に集光させた光束の最良波面収差が、 $0.05\lambda_{rms}$ 以下となるように第1非球面と共通屈折面とを設計すると共に、透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体に1次光により集光させた光束の球面収差の発生量が、第2の光情報記録媒体に第1非球面を介して集光させたときの球面収差の発生量より少なくなるように、前記共通屈折面に対する第1回折面を、その光軸側縁の

開口数が0.35以上であるように設計する。第1光情報記録媒体の記録再生を行なう場合、回折面によって回折された第2光情報記録媒体用の光束がフレアとなるのを避けることは出来ない。対物レンズへの入射光束が、ガウシアン分布であれば、光軸付近の光強度が大きいので、開口数を小さくすればこの強度の大きい部分を回折することとなり、スポット光量が不足し、一方、ボトムジッターが悪化する。従って、第2分割面である回折面の光軸側縁の開口数は0.35以上であることが望ましい。これら第1非球面と第1回折面とを、上記第2光情報記録媒体の記録再生に必要な対物レンズの情報記録面側の開口数を $NA_2$ （ただし、 $NA_2 < NA_1$ ）としたとき、上記第1非球面の上記 $NA_2$ 近傍の光束が通過する部分に上記第1回折面が位置するように合成する。このとき、上記第1非球面の軸上曲率半径と、上記第1回折面の軸上曲率半径とを同一として設計することが好ましく、上記第1非球面は、合成する第1回折面よりも光軸側に位置する第1非球面を通過し、透明基板の厚さが $t_2$ の第2光情報記録媒体に集光させた光束の最良波面収差が $0.07\lambda_{rms}$ 以下であることが望ましい。対物レンズの構成は、実施例の説明中でより具体的に記載にする。

【0013】

【実施例】以下図面を参照して、実施例によって本発明をさらに詳細に説明する。実施例に先立ち、本発明を実施する光ピックアップ装置について説明する。図5は本発明を実施する光ピックアップ装置の構成を示す概念図であり、光ピックアップ装置10は光源である半導体レーザ11、偏光ビームスプリッタ12、コリメータレンズ13、 $1/4\lambda$ 板14、絞り17、対物レンズ16、非点収差素子であるシリンドリカルレンズ18、光検出器30、およびフォーカス制御およびトラッキング制御のための2次元アクチュエータ15などからなる。

【0014】光源である半導体レーザ11からの光束は、偏光ビームスプリッタ12、コリメータレンズ13および $1/4\lambda$ 板14を透過して円偏光の平行光束となり、絞り17により絞られ、対物レンズ16によって光ディスク20の透明基板21を介して情報記録面22上に集光される。情報記録面22で情報ビットにより変調された反射光束は、再び対物レンズ16、 $1/4\lambda$ 板14、コリメータレンズ13により収束光となり、偏光ビームスプリッタ12で反射し、シリンドリカルレンズ18を経て光検出器30に入射する。その出力信号を用いて光ディスク20に情報記録された情報の読み取り信号が得られる。一方、光検出器30上でのスポットの形状変化による光量分布変化を検出して合焦検出やトラック検出を行なう。光検出器30からの出力を用いて周知のように図示しない演算回路によってフォーカスエラー信号およびトラッキングエラー信号が生成され、このフォーカスエラー信号に基づいて2次元アクチュエータ15

が、光束を情報記録面22上に結像するように対物レンズ16を光軸方向に移動させ、同時にトラッキングエラー信号に基づいて光束を所定のトラックに結像するように対物レンズ16を光軸と垂直な方向に移動させる。

【0015】このような光ピックアップ装置10において、透明基板の厚さが $t_1$ の第1光ディスク、例えばDVD( $t_1=0.6\text{mm}$ )を記録再生する際には、ビームスポットが最小錯乱円を形成するよう(ベストフォーカス)に対物レンズ16を、2次元アクチュエータ15により駆動する。この対物レンズ16を用いて、透明基板の厚さが $t_1$ と異なる $t_2$ (好ましくは $t_2>t_1$ )で情報記録密度が第1光ディスクよりも低い第2光ディスク、例えばCD( $t_2=1.2\text{mm}$ )を記録再生する際には、透明基板の厚さが異なる(好ましくはお大きくなる)ことで球面収差が発生し、ビームスポットが最小錯乱円となる位置(近軸焦点位置より後方の位置)では、スポットサイズが大きく第2光ディスクのビット(情報)を読むことは出来ない。しかしながら、この最小錯乱円となる位置より対物レンズ16に近い前側位置(前ピン)では、スポット全体の大きさは最小錯乱円よりも大きい、中央部に光量が集中した核と、核の周囲に不要光であるフレアとが形成される。この核を第2光ディスクのビット(情報)を読むために利用し、第2光ディスク記録再生時には、対物レンズ16をデフォーカス(前ピン)状態になるように2次元アクチュエータ15を駆動する。

【0016】次に、上記のような透明基板の厚さが異なる第1光ディスクと第2光ディスクを1つの光ピックアップ装置10で再生するために、対物レンズ16に本発明を実施した例を説明する。図1は、対物レンズ16を模式的に示した断面図である。なお、一点鎖線は光軸を示している。図示の第1光ディスク20は、その透明基板の厚さ $t_1$ は、第2の光ディスクの透明基板の厚さ $t_2$ よりも薄く、情報記録密度は第2光ディスクよりも大きい。

【0017】本実施例において、対物レンズ16は、光源側の面S1および光ディスク20側の屈折面S2は共に非球面形状を呈した正の屈折力を有した凸レンズである。また、対物レンズ16の光源側の面S1は光軸と同心状に複数(本実施例では3つ)の第1分割面Sd1～第3分割面Sd3から構成されている。分割面Sd1～Sd3の境界は段差を設けて、かつ第2分割面Sd2にはホログラムが形成されている。この対物レンズ16において、光軸を含む第1分割面Sd1を通過する光束(第1光束)は第1光ディスクに記録された情報の再生および第2光ディスクに記録された情報の再生に利用し、第1分割面Sd1より外側の第2分割面Sd2で回折される光束(第2光束)は主に0次光が第1光ディスクおよび1次回折光が第2ディスクに記録された情報の再生に利用し、第2分割面Sd2より外側の第3分割面

Sd3を通過する光束(第3光束)は主に第1光ディスクに記録された情報の再生に利用するような形状となっている。

【0018】このように、光源から出射される光束を、光軸近傍の第1光束を第1光ディスクの再生および第2光ディスクの再生に利用し、第1光束より外側の第2光束を第1光ディスクおよび第2光ディスクの再生に利用し、第2光束より外側の第3光束を主に第1光ディスクの再生に利用することにより、光源からの光を光量損失を抑えつつ、1つの集光光学系で複数(本実施例では2つ)の光ディスクの再生が可能となる。しかもこの場合、第2光ディスクの再生時には第3光束の大部分は不要光であるが、この不要光が第2光ディスクの再生には利用されないで、絞り17を第1光ディスクの再生に必要な開口数にしておくだけで、絞り17の開口数を変える手段を何ら必要とせずに再生することが出来る。

【0019】さらに詳述すると、本実施例の対物レンズ16は、第1光ディスクを再生する際には(図2参照)第1分割面Sd1および第3分割面Sd3を通過する第1光束および第3光束(斜線で示される光束)および第2分割面Sd2の0次回折光は、ほぼ同一の第1結像位置に結像し、その波面収差(第2分割面Sd2を通過する第2光束を除いた波面収差)は、 $0.05\lambda_{\text{rms}}$ 以下となっている。ここで $\lambda$ は光源の波長である。これにより、第1光束、第2光束および第3光束で第1光ディスクの再生が行なわれる。

【0020】このとき、第2分割面Sd2を通過する第2光束の1次回折光(破線で示される光束)は、第1結像位置とは異なった第2結像位置に結像する。この第2結像位置は第1結像位置を0(零)として、それより対物レンズ16側を負、その反対側を正とすると、第1結像位置から $-27\mu\text{m}$ 以上 $-4\mu\text{m}$ 以下の距離にする

(第2結像位置を第1結像位置より対物レンズに近付ける。)。この下限 $-27\mu\text{m}$ を越えると、球面収差の補正し過ぎとなり、第1光ディスクの再生時のスポット状況が悪くなり、また、上限 $-4\mu\text{m}$ を越えると、第2光ディスクの再生時のスポット径、サイドローブが大きくなる。なお、本実施例では、 $t_1<t_2$ 、 $NA_1>NA_2$ であるので、第2結像位置を第1結像位置から $-27\mu\text{m}\sim-4\mu\text{m}$ としたが、 $t_1>t_2$ 、 $NA_1<NA_2$ の場合は、第2結像位置を第1結像位置から $4\mu\text{m}\sim27\mu\text{m}$ にする。

【0021】また、上記の対物レンズ16を所定の厚さ( $t_2=1.2\text{mm}$ )の透明基板を有する第2光ディスクの再生に使用するには、図2に示すように対物レンズ166に入射する所定の光束(平行光束)の場合、第1光束(右肩上がりの斜線で示す)のうち光軸近傍を通過する光線が光軸と交わる位置と、光軸と直交する方向で第1分割面Sd1の端部(第2分割面Sd2側)を通過する光線が光軸と交わる位置との間に、第2光束(右肩

下がりの斜線で示す)の1次回折光が光軸と交わる(結像する)ようになる。よって、第1光束および第2光束は、第2光ディスクの情報記録面近傍に集光され、第2光ディスクの再生が行なわれる。このとき、第3光束(途中まで破線で示される)はフレアとなるが、第1光束および第2光束で形成される核により第2光ディスクの再生が可能となる。

【0022】換言すると、本発明は、開口数の小さい光軸近傍を通過する第1光束を、再生できる全ての光ディスクの再生に利用し、また、第1分割面より外側を通過する第2光束を再生する各光ディスクに対応するように分け、分けられた各光束を各光ディスク(本実施例では第1、第2光ディスク)の再生に利用する。さらに、光ディスクの情報を再生するために必要な開口数が多い方の光ディスク(本実施例では第1光ディスク)の再生には分けられた光束のうち第1光束から離れた光束(本実施例では第3光束)を利用する。

【0023】このような光学系(本実施例では対物レンズ16)を用いると、透明基板の厚さが異なる複数のディスクを1つの光学系で再生することが可能となり、また、任意に分割面径を設定できることにより、第2光ディスクの再生に必要な開口数 $NA_2$ を大きくすることが出来る。また、光軸近傍の光束を複数の光ディスクの再生に利用することで、光源からの光束の光量損失が少なくなる。しかも、第2光ディスク再生時には、ビームスポットのサイドローブを減少させ、ビーム強度の強い核を形成し、正確な情報が得られる。さらに、絞り17の開口数を変更する特別な手段を必要とせずに複数のディスクを1つの集光光学系で再生することができる。

【0024】なお、本実施例では、分割面 $Sd1 \sim Sd3$ および回折面を対物レンズ16の光源側の面 $S1$ に設けたが、ディスク20側の屈折面に設けてもよく、また、他の集光光学系の光学素子(例えば、コリメータレンズ13など)の1つにこのような機能を持たせてもよく、さらに、新たにこのような機能を有する光学素子を光路上に設けてもよい。また、各分割面 $Sd1 \sim Sd3$ の機能を異なる光学素子に分解して設けてもよい。

【0025】また、本実施例では、コリメータレンズ13を用いた、いわゆる無限系の対物レンズ16を用いたが、コリメータレンズ13がなく、光源からの発散光が直接または発散光の発散度合いを減じるレンズを介した発散光が入射するような対物レンズや、光源からの光束を収斂光に変更するカップリングレンズを用い、その収斂光が入射するような対物レンズに適用してもよい。

【0026】また、本実施例では、面 $S1$ を3つの分割面 $Sd1 \sim Sd3$ で構成したが、これに限らず、少なくとも3つ以上の分割面で構成すればよい。たとえば、面 $S1$ を5つの分割面 $Sd1 \sim Sd5$ で構成したこの場合、第2および第4分割面をホログラムとし、第3分割面と第4分割面の境界の開口数を $NA_3$ 、第4分割面と

第5分割面との境界の開口数を $NA_4$ としたとき、 $0.60(NA_2) < NA_3 < 1.3(NA_2)$ 、 $0.01 < NA_4 - NA_3 < 0.12$ の条件を満足することが好ましい。これにより、第1ディスクに集光させる光スポットの強度を落とすことなく、第2光ディスクとしてより大きな必要開口数のディスクを再生することが出来る。さらに、 $NA_3$ の上限は $NA_3 < 1.1(NA_2)$ であることが実用上好ましく、また $NA_3$ の下限は $0.80(NA_2) < NA_3$ が好ましく、さらに $0.85(NA_2) < NA_3$ であることが実用上好ましい。また、 $NA_4 - NA_3$ の上限は、 $NA_4 - NA_3 < 0.1$ であることが好ましい。

【0027】また、本実施例では、光源から対物レンズ16を見たときに、第2分割面 $Sd2$ を光軸と同心円状の環形状のホログラムを設けたが、これに限られず、フレネルで構成してもよい。なお、0次光と1次光とに分けた光束の一方を第1光ディスクの再生に利用し、他方を第2光ディスクの再生に利用する。このとき、第2光ディスクの再生に利用する光束の光量を大きくしてもよい。さらに、主に0次光と1次光とを利用する回折面を設けたが、1次光と2次光を利用する回折面としたり、高次光を利用する回折面としてもよい。

【0028】また、本実施例において、第1ディスクを再生する際(すなわち、厚さ $t_1$ の透明基板を介したとき)第1分割面 $Sd1$ および第3分割面 $Sd3$ を通過する光束による最良波面収差が $0.05\lambda_{rms}$ (ただし、 $\lambda$ (nm)は第1ディスクを再生する際に使用する光源の波長)を満たすだけでなく、さらに、第2光ディスクを再生する際(すなわち、厚さ $t_2$ の透明基板を介したとき)第1分割面 $Sd1$ を通過する光束による最良波面収差が回折限界である $0.07\lambda_{rms}$ (ただし、 $\lambda$ (nm)は第2ディスクを再生する際に使用する光源の波長)を満たすことにより、第2光ディスクの再生信号を良好にすることが出来る。

【0029】次に、第2の実施例について、対物レンズ16の球面収差図を模式的に示した図である図3を参照して説明する。図3において(a)は第1ディスクを再生、すなわち厚さ $t_1$ の透明基板を介したときの球面収差であり、(b)は第2ディスクを再生、すなわち、厚さ $t_2$ (本実施例では $t_2 > t_1$ )の透明基板を介したときの球面収差である。ここで、第1光ディスクの情報を再生するために必要な集光光学系の光ディスク側の必要開口数を $NA_1$ 、第2光ディスクの情報を再生するために必要な集光光学系の光ディスク側の必要開口数を $NA_2$ (ただし、 $NA_2 < NA_1$ )、対物レンズ16の分割面 $Sd1$ と $Sd2$ との境界を通過する光束の光ディスク側の開口数を $NA_L$ 、対物レンズ16の分割面 $Sd2$ と $Sd3$ との境界を通過する光束の光ディスク側の開口数を $NA_H$ とする。

【0030】なお、第2の実施例は上記の第1実施例と



して記載した対物レンズ16を別の観点(球面収差、形状、波面収差など)から見たものであって、以下に記載しない部分は上記実施例と同様である。

【0031】上記第1実施例のような対物レンズ16は、まず、透明基板の厚さが $t_1$ の第1光ディスクに集光させた光束の最良波面収差が $0.05\lambda_{rms}$ 以下となるように第1屈折面S1の第1非球面(輪帯状分割面)と第2屈折面S2(共通屈折面)を設計する。この設計により得られたレンズの球面収差が図3(a)である。そして、0次光は第1光ディスク使用時には球面収差に影響を与えず、1次回折光はこの第1非球面を有するレンズを介して透明基板の厚さが $t_2$ ( $t_2 \neq t_1$ )の第2光ディスクに集光させたときの球面収差の発生量(図3(c))よりも、少ない球面収差となるように第2屈折面S2(共通屈折面)はそのままで第1回折面を設計する。このとき第1回折面の近軸曲率半径と第1非球面の近軸曲率半径とは同じにすることが、デフォーカス状態で再生を行なう第2光ディスクの再生を良好に行なうために好ましい。この設計により得られたレンズの第2光ディスクに集光させたときの球面収差が図3(d)であり、また、このレンズで第1光ディスクに集光させたときのレンズの収差図が図3(a)である。そして、この第1非球面の第2光ディスクの必要開口数NA2近傍で第1回折面を合成する。

【0032】従って、この対物レンズ16の屈折面S1における面形状としては、光軸を含む第1分割面Sd1と第1分割面Sd1より外側の第3分割面Sd3とは同じ非球面形状(第1非球面)となり、その第1分割面Sd1と第3分割面Sd3との間(第2光ディスクの再生に必要な開口数NA2近傍、すなわち、NAL~NAH)の第2分割面Sd2は、第1分割面Sd1および第3分割面Sd3とは異なる面形状となる。得られたレンズが本実施例の対物レンズ16となり、この対物レンズ16を用いて第1光ディスクに集光させたときの球面収差図は図3(a)となり、第2光ディスクに集光させたときの球面収差図は図3(b)となる。

【0033】上述したように、本実施例において得られた対物レンズ16は、開口数NA2の近傍の少なくとも2つの開口位置(NALとNAH)で、透明基板の厚さが異なる複数のディスクを1つの集光光学系で再生できるように、球面収差が不連続に変化するように構成している。このように球面収差が不連続に変化するようにしたので、各々の開口数の範囲(本実施例では光軸~NALの第1分割面、NALからNAHの第2分割面、NAH~NA1の第3分割面)を通過する光束(本実施例では第1光束~第3光束)を任意に構成することが出来、第1光束を再生する複数の光ディスク全ての再生に利用し、第2光束および第3光束をそれぞれ複数の光ディスクのうち所定の光ディスクの再生に利用することが可能となり、1つの集光光学系(本実施例では対物レンズ1

6)で複数の光ディスクを再生出来、低コストかつ複雑化しないで実施出来、さらに、高NAの光ディスクにも対応できる。しかも絞り17は、高NAであるNA1に対応するように設けるだけでよく、光ディスク再生に必要な開口数に変化(NA1或いはNA2に)したとしても、絞り17を変化させる手段を何ら設ける必要もない。なお、「球面収差が不連続に変化する」とは、球面収差図で見たときに急激な球面収差の変化が見られることを云う。

10 【0034】さらに、球面収差の不連続に変化する方向は、小さい開口数から大きい開口数へと見たときに、開口数NALでは球面収差が負の方向に、開口数NAHでは球面収差が正の方向になっている。これにより、薄い透明基板の厚さ $t_1$ の光ディスクの再生が良好になるとともに、これより厚い透明基板の厚さ $t_2$ の光ディスクの再生が良好に行なうことが出来る。なお、本実施例では $t_2 > t_1$ 、 $NA1 > NA2$ であるために、上述したように球面収差は、開口数NALでは負の方向に、開口数NAHでは正の方向に不連続に変化するが、 $t_2 < t_1$ 、 $NA1 > NA2$ の場合は、開口数NALでは正の方向に、開口数NAHでは負の方向に球面収差が不連続に変化することになる。

20 【0035】さらに、透明基板の厚さ $t_2$ の第2光ディスクを再生する際には、開口数NALから開口数NAHまでの間の球面収差(第2分割面Sd2により回折された光束による球面収差)が正となるようにすることにより、光ピックアップ装置10のS字特性が向上する。なお、本実施例では $t_2 < t_1$ 、 $NA1 > NA2$ であるために、開口数NALから開口数NAHまでの間の球面収差が正となるようにしたが、 $t_2 < t_1$ 、 $NA1 > NA2$ の場合は、負とするといふ。

30 【0036】また、本実施例の対物レンズ16の波面収差を図4に示す。図4は縦軸に波面収差( $\lambda$ )、横軸に開口数をとった波面収差曲線であり、(a)は第1光ディスクの透明基板(厚さ $t_1$ )を介したときを、(b)は第2光ディスクの透明基板(厚さ $t_2$ )を介したときの波面収差を実線で表している。なお、この波面収差は、それぞれの透明基板を介したときに最良の波面収差となる状態で干渉計などを用いて波面収差を測定して得る。

40 【0037】図4(b)からわかるように、本実施例の対物レンズ16は、波面収差曲線で見ると、開口数NA2近傍の2か所(具体的にはNALとNAH)で波面収差が不連続となっている。また、不連続となっている部分に発生する最大の波面収差の不連続量は、長さの単位(mm)で表すと、 $0.05(NA2)^2$ (mm)以下、位相の単位(rad)で表すと、 $2\pi\{0.05(NA2)^2\}/\lambda$ (rad)以下(ただし、この場合 $\lambda$ は使用波長で単位はmm)とすることが望ましい。これ以上では、波長変動による波面収差の変動が大きくな



り、半導体レーザーの波長のバラツキを吸収出来なくなる。さらに、この不連続の部分（NALとNAHの間）の波面収差の傾きは、不連続となっている部分の両側の曲線の端部を結ぶ曲線（図4（a）の破線）の傾きとは異なっている。なお、本実施例では分割面Sd1～SD3を対物レンズ16の光源側の面S1に設けたが、光ディスク20側の屈折面に設けてもよい。

【0038】また、本実施例では、コリメータレンズ13を用いた、いわゆる無限系の対物レンズ16を用いたが、コリメータレンズ13がなく、光源からの発散光が直接または発散光の発散度合いを減じるレンズを介した発散光が入射するような対物レンズや、光源からの光束を収斂光に変更するカップリングレンズを用い、その収斂光が入射するような対物レンズによってもよい。

【0039】本実施例において、第1非球面を設計する際には、前述のように厚さ $t_1$ の透明基板を介したとき第1分割面Sd1と第3分割面Sd3を通過する光束による最良波面収差が $0.05\lambda_{rms}$ （ただし、 $\lambda$ （nm）は第1ディスクを再生する際に使用する光源の波長）以下とするだけでなく、厚さ $t_2$ の透明基板を介したとき第1分割面Sd1を通過する光束による最良波面収差が回折限界である $0.07\lambda_{rms}$ （ただし、 $\lambda$ （nm）は第2ディスクを再生する際に使用する光源の波長）を満たすように設計を行なうことにより、第2光ディスク再生信号を良好にすることができる。

【0040】次に、波長の異なる2つの光源を有する光ピックアップ装置における実施例を示す。図5の光ピックアップ装置は1つの光源111を用いるものであったが、図6に示す光ピックアップ装置10は光源111と112の2つを用いる。図5中の素子と同じ素子は同じ符号で示す。第1光ディスクの再生用に、第1光源である第1半導体レーザー111（波長 $\lambda_1=610\text{nm}\sim 670\text{nm}$ ）と、第2光ディスクの再生用に第2光源である第2半導体レーザー112（波長 $\lambda_2=740\text{nm}\sim 870\text{nm}$ ）とを有している。また、合成手段19は、第1半導体レーザー111から出射された光束と第2半導体レーザー112から出射された光束とを合成することが可能な手段であって、両光束を1つの集光光学系を介して光ディスク20に集光させるために、同一光路とする手段である。

【0041】まず、第1ディスクを再生する場合、第1半導体レーザー111からビームを出射し、出射された光束は合成手段19、偏光ビームスプリッタ12、コリメータレンズ13、1/4波長板14を透過して円偏光の平行光束となる。この光束は、絞り17によって絞られ、対物レンズ16により第1光ディスク20の透明基板21を介して情報記録面22上に集光される。そして情報記録面22で情報ビットにより変調されて反射した光束は、再び対物レンズ16、1/4波長板14、コリメータレンズ13を透過して偏光ビームスプリッタ12

に入射し、ここで反射してシリンドリカルレンズ18により非点収差が与えられ光検出器30上へ入射し、光検出器30から出力される信号を用いて第1光ディスク20に記録された情報の読み取り信号が得られる。また、光検出器30上でのスポットの形状変化による光量分布変化を検出して合焦検出やトラック検出を行なう。この検出に基づいて2次元アクチュエータ15が、半導体レーザー111からの光束を第1光ディスクの情報記録面22上に結像するように対物レンズ16を光軸方向に移動させるとともに、光束を所定のトラックに結像するように対物レンズ16を光軸と垂直な方向に移動させる。

【0042】一方、第2ディスクを再生する場合、第2半導体レーザー112からビームを出射し、出射された光束は合成手段19により光路を変更され、その後、偏光ビームスプリッタ12、コリメータレンズ13、1/4波長板14、絞り17、対物レンズ16を介して第2光ディスク20上に集光される。そして、情報記録面22で情報ビットにより変調されて反射した光束は、再び対物レンズ16、1/4波長板14、コリメータレンズ13、偏光ビームスプリッタ12、シリンドリカルレンズ18を介して光検出器30上へ入射し、光検出器30から出力される信号を用いて第2光ディスク20に記録された情報の読み取り信号が得られる。また、光検出器30上でのスポットの形状変化による光量分布変化を検出して合焦検出やトラック検出を行なう。この検出に基づいて2次元アクチュエータ15が、半導体レーザー112からの光束を第1光ディスクの情報記録面22上にデフォーカス状態で結像するように対物レンズ16を光軸方向に移動させるとともに、光束を所定のトラックに結像するように対物レンズ16を光軸と垂直な方向に移動させる。

【0043】このような光ピックアップ装置10の集光光学系の1つである対物レンズ16に、先の実施例のような対物レンズを用いる。すなわち、対物レンズ16は、光源側の面S1および光ディスク側の屈折面S2は共に非球面形状を呈した正の屈折力を有する凸レンズであり、光源側の面S1は、光軸と同心上に複数（本実施例では3つ）の第1分割面Sd1～第3分割面Sd3から構成され、分割面Sd1～Sd3の境界は段差を設ける。そして、第1分割面Sd1および第3分割面Sd3は、第1光源111から出射して第1光ディスクに集光させた光束の最良波面収差が $0.05\lambda_{rms}$ 以下となるような第1非球面で形成し、また、第2分割面は、第1非球面を有するレンズを介して第2光源112の光束を透明基板の厚さが $t_2$ （ $t_2 \neq t_1$ ）の第2光ディスクに集光させたときの球面収差の発生量よりも少ない球面収差となるように回折面で形成し、この第1非球面の第2光ディスクの必要開口数NA2近傍であるNAL～NAHに、回折面を合成した対物レンズとする。得られた対物レンズ16は、以下の点を除き先の実施例と同様

の構成、作用、効果を持つこととなり、さらに、2つの光源を用いるので、複数の光ディスクを再生するに際して自由度が大きくなる。

【0044】本実施例では、2つの光源111、112を用いるので、以下の好ましい範囲が先の実施例と異なる。すなわち、 $t_1 = 0.6 \text{ mm}$ 、 $t_2 = 1.2 \text{ mm}$ 、 $610 \text{ nm} < \lambda_1 < 670 \text{ nm}$ 、 $740 \text{ nm} < \lambda_2 < 870 \text{ nm}$ 、 $0.4 < NA_2 < 0.51$ としたとき、 $0.60 (NA_2) < NAL < 1.1 (NA_2)$ の条件（この下限0.60 (NA2)は実用上、0.80 (NA2)が好ましく、さらに0.85 (NA2)であることが好ましい。）を満たすことが好ましい。この下限を超すとサイドローブが大きくなり、情報の正確な再生が出来ず、上限を超すと波長 $\lambda_2$ と $NA_2$ において想定される回折限界スポット径以上に絞られ過ぎる。なお、ここで云うNALは第2光源112を用いたときの第2分割面Sd2上でのNALを指す。

【0045】また、 $0.01 < NAH - NAL < 0.12$ （この上限0.12は、実用上、0.1であることがさらに好ましい。）の条件を満たすことが好ましい。この下限を超すと第2光ディスクの再生時のスポット形状が悪化し、サイドローブ・スポット径が大きくなり、上限を超すと第1光ディスクの再生時のスポット形状が乱れ、光量低下を引き起こす。なお、ここでいうNAHおよびNALは、第2光源112を用いたときの第2分割面Sd2上でのNAHおよびNALを指す。

【0046】また、第2光ディスクの再生時（ $t_2$ の厚さの透明基板を介した際）に、開口数NALから開口数NAHの間の球面収差が、 $-2(\lambda_2)/(NA_2)^2$ 以上、 $5(\lambda_2)/(NA_2)^2$ 以下の条件を満たすことが好ましい。さらに、この条件は、再生の場合は $3(\lambda_2)/(NA_2)^2$ 以下が好ましく、或いは、記録をも考慮すると（もちろん、再生もできる。）0（零）より大きいことが好ましい。この下限を超すと球面収差の補正し過ぎとなり第1光ディスク再生時のスポット形状が悪化し、上限を超すと第2光ディスクの再生時のスポット形状が悪化し、サイドローブ・スポット径が大きくなる。特に、この条件は、 $0 \sim 2(\lambda_2)/(NA_2)^2$ の範囲を満足することがさらに好ましく、この場合、フォーカスエラー信号が良好に得られる。

【0047】また、別の観点から見ると、 $0.60 (NA_2) < NA_3 < 1.1 (NA_2)$ の条件（この下限0.60 (NA2)は実用上0.80 (NA2)が好ましく、さらに0.85 (NA2)であることが好ましい。）を満足すると共に、 $0.01 < NA_4 - NA_3 < 0.12$ （好ましくは0.1）の条件を満足する対物レンズ16の光ディスク側の開口数 $NA_3$ と開口数 $NA_4$ の間に、前述したNALとNAHとを設ける（すなわち、主に第2光ディスクの再生に利用する分割面を設ける。）ことである。これにより、第1光ディスクに集光

させる光スポットの強度を落とすことなく、第2光ディスクとしてより大きな必要開口数の光ディスクを再生することが出来る。

【0048】特に、 $t_2 > t_1$ 、 $NA_1 > NA_2$ で、光軸から円周方向へとみたとき、開口数NALでは、屈折面の法線と光軸との交点が、光源側の屈折面に近づく方向に不連続に変化し、開口数NAHでは、屈折面の法線と光軸との交点が、光源側の屈折面から遠のく方向に不連続に変化している。これにより、薄い透明基板の厚さ $t_1$ の光ディスクの再生が良好になると共に、これより厚い透明基板の厚さ $t_2$ の光ディスクの再生が良好に行なうことが出来る。

【0049】また、先の実施例と同様に、別の観点から本実施例を見ると、少なくとも一方の面を光軸と同心状に分割された複数の分割面（本実施例では3つの分割面）を有する対物レンズ16において、第1分割面Sd1を透過した光と、第3分割面Sd3を透過した光とが、所定の厚さ（第1光ディスク）の透明基板を介して、ほぼ同じ位相となるようにしたとき、第1分割面Sd1を透過し透明基板を介した光と、第2分割面Sd2のほぼ中央位置より光軸側の第2分割面Sd2を透過し透明基板を介した光と、の位相差を $(\Delta 1L)\pi \text{ (rad)}$ とし、第3分割面Sd3を透過し透明基板を介した光と、前記中央位置より光軸側とは反対側の第2分割面Sd2を透過し透明基板を介した光と、の位相差を $(\Delta 1H)\pi \text{ (rad)}$ とすると、 $(\Delta 1H) > (\Delta 1L)$ を満足する。この場合も上記と同様に、 $t_1 > t_2$ 、 $NA_1 > NA_2$ の場合は、 $(\Delta 1H) < (\Delta 1L)$ とする。したがって、 $(\Delta 1H) \neq (\Delta 1L)$ とする。

【0050】なお、先の実施例と同様、分割面Sd1～Sd3を対物レンズ16の屈折面S1に設けること、無限系の対物レンズを用いること、分割面に段差を設けること、分割面の数、第2分割面の面形状など、本実施例についての記述に限られるものではない。また、第1光源111と第2光源112とを合成手段19により合成するようにしたが、これに限られず、図1に示した光ピックアップ装置において光源11を第1光源111と第2光源112とに切り替わるようにしてもよい。

【0051】また、本実施例において、第1光ディスクを再生する際（すなわち、厚さ $t_1$ の透明基板を介したとき）第1分割面Sd1および第3分割面Sd3を通過する光束による最良波面収差が $0.05 \lambda \text{ rms}$ （ただし、 $\lambda \text{ (nm)}$ は第1光ディスクを再生する際に使用する光源の波長）を満たすだけでなく、さらに、第2光ディスクを再生する際（すなわち、厚さ $t_2$ の透明基板を介したとき）第1分割面Sd1を通過する光束による最良波面収差が回折限界である $0.07 \lambda \text{ rms}$ （ただし、 $\lambda \text{ (nm)}$ は第2光ディスクを再生する際に使用する光源の波長）を満たすことにより、第2光ディスクの再生信号を良好にすることが出来る。

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【0052】なお、この実施例における対物レンズ16においては、本特許出願人が先の実施例に示す光ピックアップ装置に用いたところ、第1光ディスクとしてDVDの再生は勿論のこと、同じ波長の光源で第2光ディスクとしてのCDの再生も可能であった。すなわち、本実施例の対物レンズ16は、波長 $\lambda_1$ の光源を用いて透明基板の厚さが $t_1$ の第1光情報記録媒体および透明基板の厚さが $t_2$ （ただし、 $t_2 \neq t_1$ ）の第2光情報記録媒体の情報記録面上に集光させることが出来ると共に、波長 $\lambda_2$ （ただし、 $\lambda_2 \neq \lambda_1$ ）の光源を用いた場合であつても第2光情報記録媒体の情報記録面上に集光することができるものである。このことにより、波長の異なる2つの光源を使用しDVDとCD-Rの再生をする光ピックアップ装置（DVD用に波長610nm～670nmの光源とCD-R用に必須な波長780nmの光源に対応）に用いる対物レンズと、1つの光源でDVDやCDの再生をする光ピックアップ装置（波長610nm～670nmの光源に対応）に用いる対物レンズとを共通化することが出来、大量生産に伴う低コスト化を実現することが出来る。なお、このように共通化できるのは、光源の波長が $\lambda_2$ から $\lambda_1$ に変えたとしても、先の実施例に記載したNALやNAHの条件を満足することが必要である。

【0053】なお、本実施例においては、第1光源111と第2光源112とをほぼ同じ倍率で使用しているので、1つの光検出器30とすることができ、構成を簡単にすることが出来るが、各々の光源111、112に対応させて2つの光検出器を設けてもよく、さらに倍率を異ならせてもよい。

【0054】以下、本発明を対物レンズ16の光源側の屈折面に適用した場合の1例のレンズデータを示す。第1光ディスクとしてDVD（透明基板の厚さ $t_1=0.6$ mm、必要な開口数 $NA1=0.60$ （ $\lambda=635$ nm））を用い、第2光ディスクとしてCD（透明基板の厚さ $t_2=1.2$ mm、必要な開口数 $NA2=0.36$ （ $\lambda=635$ nm）あるいは $NA2=0.45$ （ $\lambda=780$ nm））或いはCD-R（透明基板の厚さ $t_2=1.2$ mm、必要な開口数 $NA2=0.50$ （ $\lambda=780$ nm））（ただし、再生のみの場合は、 $NA2=0.4*$

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\*5（ $\lambda=780$ nm））を用いることにする。なお、以下の対物レンズ16の例においては、コリメータレンズ13は、設計を最適にすることにより対物レンズ16へはほぼ無収差の平行光束を入射させることができるため、以下の例においては対物レンズ16へ平行光束が入射して以降の構成を示す。また、対物レンズ16の光源側に配置される絞りを第1面として、ここから順に第 $i$ 番目のレンズ面の曲率半径を $r_i$ 、DVD再生時の第 $i$ 番目の面と第 $i+1$ 番目の面との間の距離を $d_i$ （CD再生時は、 $d_i'$ に記載がある場合はその数値に変わり、記載がない場合は $d_i$ と同じである。）、その間隔のレーザ光源の光束の波長での屈折率を $n_i$ で表している。また、光学面に非球面を用いた場合は、上述した非球面の式に基づくものとする。

【0055】（実施例1）実施例1は上述した先の実施例の1光源の光ピックアップ装置10に搭載する対物レンズ16であつて、第1分割面 $Sd1$ ～第3分割面 $Sd3$ の境界に段差を設けた対物レンズ16に本発明を実施した例である。本実施例において、非球面は次式に基づくものとする。

【数1】

$$X = \frac{H^2/r}{1 + \sqrt{1 - (1 + \kappa) (H/r)^2}} + \sum_j A_j H^{P_j}$$

但し $X$ は光軸方向の軸、 $H$ は光軸と垂直方向の軸、光の進行方向を正とし、 $r$ は近軸曲率半径、 $\kappa$ は円錐形数、 $A_j$ は非球面係数、 $P_j$ は非球面のべき数（ただし、 $P_j \geq 3$ ）である。なお、上式以外の他の非球面の式を用いてもよい。非球面形状から非球面の式を求める際には、上式を用い、 $P_j$ を $10 \geq P_j \geq 3$ の自然数とし、 $\kappa=0$ として求める。また、第1回折面は高屈折率の薄膜として表すものとする。光路差関数は $\Phi(h) = C_1 h^2 + C_2 h^4 + C_3 h^6 + C_4 h^8 + C_5 h^{10}$ で表し、基板面からの削り量は

$$L = \{\Phi(h) + i\lambda\} / (n-1) \quad i=0, 1, 2, \dots$$

である。

【0056】

【表2】

波長	650nm		780nm		
焦点距離	3.36		3.39		
絞り径	$\phi=4.04\text{mm}$				
対物レンズ横倍率	0				
i	ri	di	di'	ni	ni'
1	$\infty$	0		1	1
2	2.114	2.2		1.5377	1.5337
3	-7.963	1.757		1	1
4	$\infty$	0.6	1.2	1.58	1.58
5	$\infty$				

【表3】

## 非球面データ

## 第2面 非球面部

 $0 \leq H \leq 1.321$  (第1分割面) $1.532 \leq H$  (第3分割面)

(非球面係数)

 $\kappa = -1.1372$  $A1 = -0.30074 \times 10^{-3}$   $P1 = 3.0$  $A2 = 0.43633 \times 10^{-2}$   $P2 = 4.0$  $A3 = 0.79005 \times 10^{-2}$   $P3 = 5.0$  $A4 = -0.49422 \times 10^{-2}$   $P4 = 6.0$  $A5 = 0.12018 \times 10^{-2}$   $P5 = 7.0$  $A6 = 0.25012 \times 10^{-4}$   $P6 = 8.0$  $A7 = -0.18446 \times 10^{-4}$   $P7 = 10.0$ 

## ホログラム部

 $1.321 \leq H \leq 1.532$  (第2分割面)

(非球面係数)

 $\kappa = -1.1372$  $A1 = -0.30074 \times 10^{-3}$   $P1 = 3.0$  $A2 = 0.43633 \times 10^{-2}$   $P2 = 4.0$  $A3 = 0.79005 \times 10^{-2}$   $P3 = 5.0$  $A4 = -0.49422 \times 10^{-2}$   $P4 = 6.0$  $A5 = 0.12018 \times 10^{-2}$   $P5 = 7.0$  $A6 = 0.25012 \times 10^{-4}$   $P6 = 8.0$  $A7 = -0.18446 \times 10^{-4}$   $P7 = 10.0$ 

(光路差係数)

 $C1 = -0.10423 \times 10^{-3}$  $C2 = 0.25757 \times 10^{-3}$  $C3 = -0.20235 \times 10^{-3}$  $C4 = 0.44453 \times 10^{-4}$  $C5 = -0.39336 \times 10^{-5}$ 

## 第3面 (非球面係数)

 $\kappa = -0.23984 \times 10^2$  $A1 = -0.25083 \times 10^{-2}$   $P1 = 3.0$  $A2 = 0.10598 \times 10^{-1}$   $P2 = 4.0$  $A3 = 0.45136 \times 10^{-2}$   $P3 = 5.0$  $A4 = -0.72617 \times 10^{-2}$   $P4 = 6.0$  $A5 = -0.15133 \times 10^{-3}$   $P5 = 7.0$  $A6 = 0.13381 \times 10^{-2}$   $P6 = 8.0$  $A7 = -0.1111 \times 10^{-3}$   $P7 = 10.0$ 

【0057】また、図3(a)に厚さ $t_1 (=0.6\text{ mm})$ の透明基板を介したとき(以下、DVD再生時という)の球面収差図を、図3(b)に厚さ $t_2 (=1.2\text{ mm})$ の透明基板を介したとき(以下、CD再生時という)の球面収差図を示している。また、図4(a)にDVD再生時の最良波面収差が得られる位置にデフォーカスした状態で見たときの波面収差図を、図4(b)にCD再生時の最良波面収差が得られる位置にデフォーカスした状態で見たときの波面収差図を示している。DVD使用時のNA1での波面収差量は $0.025\lambda\text{ rms}$ 、CD使用時の第1分割面内での波面収差量は $0.054\lambda\text{ rms}$ である。また、図7(a)にDVD再生時の最良スポット形状が得られたときの集光スポットの相対強度分布図を示し、図7(b)にCD再生時に最良のスポット形状が得られたときの集光スポットの相対強度分布図を示す。

【0058】

\*【発明の効果】以上詳述したように、本発明においては、1つの集光光学系で複数の光情報記録媒体の記録再生が出来、低コストかつ複雑化しないで実現出来、さらに、高NAの光情報記録媒体にも対応できる。さらに、本発明では、球面収差の発生を積極的に利用し、複数の光情報記録媒体の記録再生を1つの集光光学系で行なうことができる。

【図面の簡単な説明】

【図1】本発明の光ピックアップ装置用対物レンズの断面模式図であり、第1光情報記録媒体への集束状況を示す。

【図2】本発明の光ピックアップ装置用対物レンズの断面模式図であり、第2光情報記録媒体への集束状況を示す。

【図3】本発明の対物レンズの各分割面の球面収差の補正状況を示す説明図である。

\* 50 【図4】本発明の対物レンズの各分割面の波面収差の補

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正状況を示す収差図である。

【図5】本発明を実施する光ピックアップ装置の構成の一例を示す概念図である。

【図6】本発明を実施する光ピックアップ装置の構成の他の例を示す概念図である。

【図7】本発明の対物レンズの最良のスポット形状の相対強度分布を示すグラフである。

【符号の説明】

11 半導体レーザ

12 偏向ビームス

ブリッタ

13 コリメータレンズ

15 アクチュエータ

17 絞り

ルレンズ

19 光束合成手段

21 透明版

30 光検出器

14  $1/4\lambda$ 板

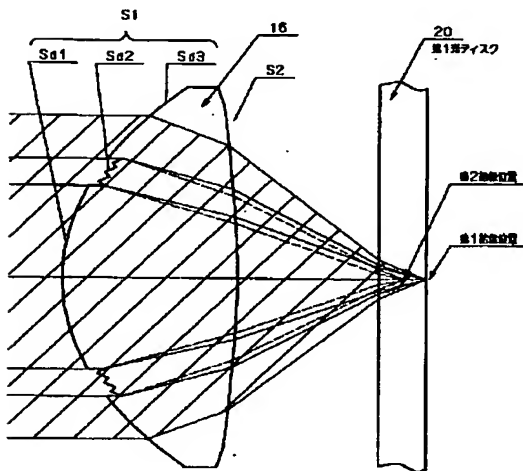
16 対物レンズ

18 シリンドリカ

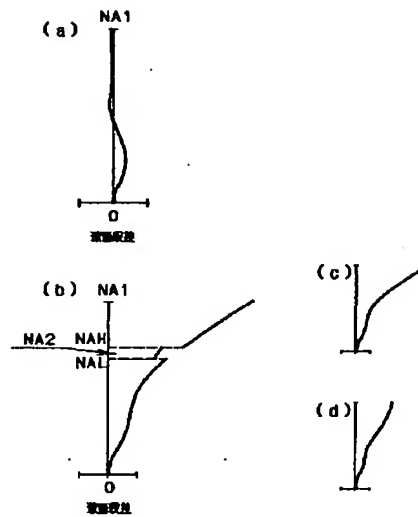
20 光ディスク

22 情報記録面

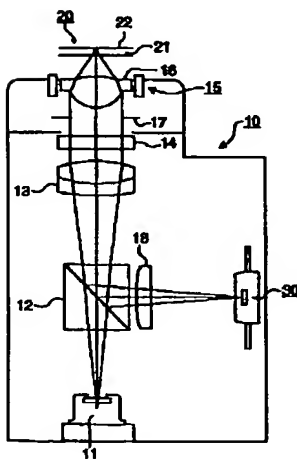
【図1】



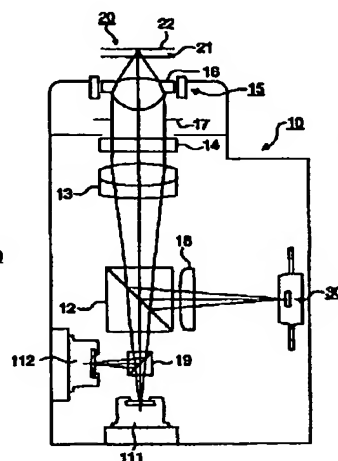
【図3】



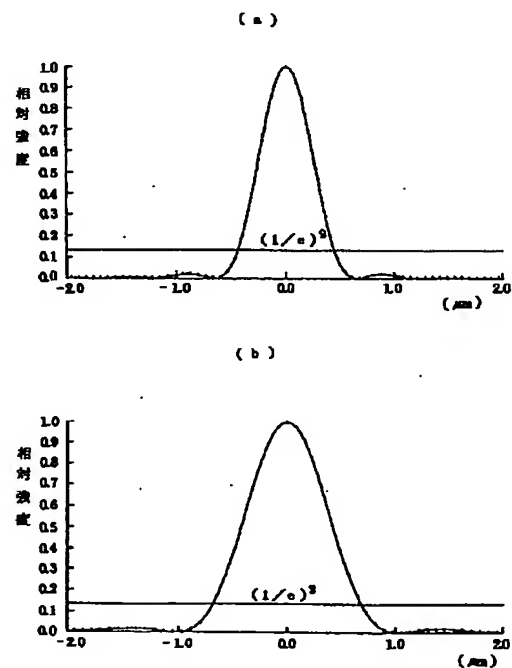
【図5】



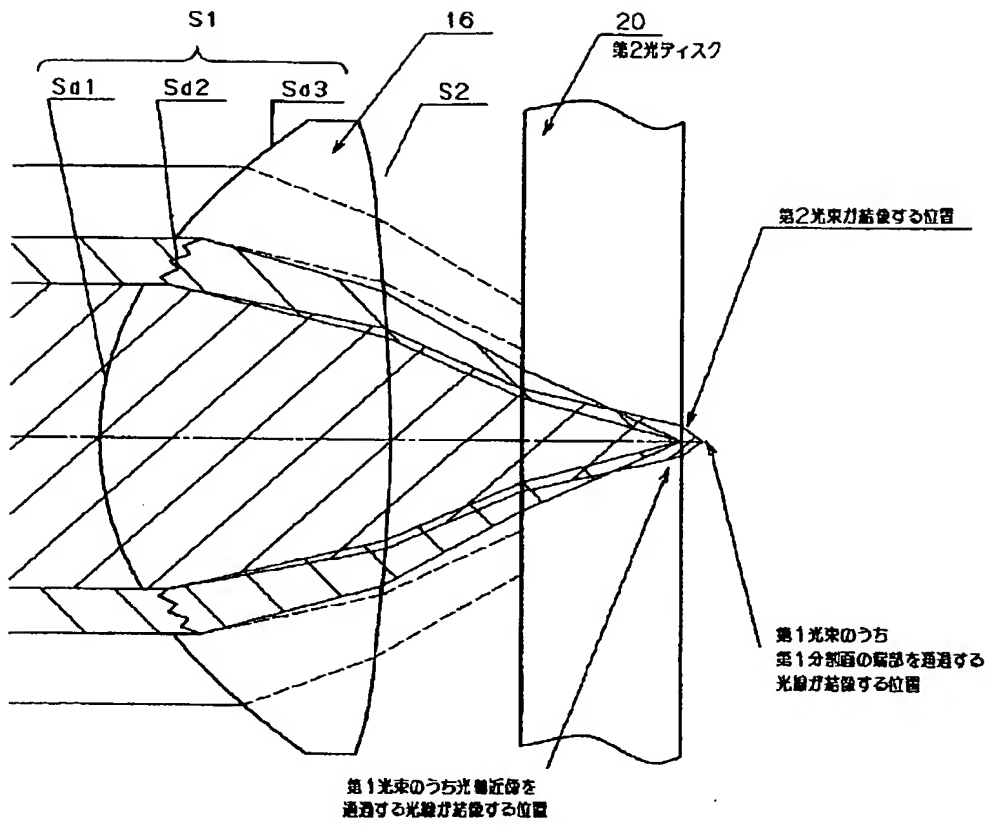
【図6】



【図7】



【図2】



【図4】

